Loyola University Chicago
Loyola eCommons

Master's Theses

Theses and Dissertations

1965

# A Study of the Changes in the Young Rhesus Monkey Mandible Following Condylectomy

Julius Guccione
*Loyola University Chicago*

## Recommended Citation

Guccione, Julius, "A Study of the Changes in the Young Rhesus Monkey Mandible Following Condylectomy" (1965). *Master's Theses.* Paper 1983.
http://ecommons.luc.edu/luc_theses/1983

This Thesis is brought to you for free and open access by the Theses and Dissertations at Loyola eCommons. It has been accepted for inclusion in Master's Theses by an authorized administrator of Loyola eCommons. For more information, please contact ecommons@luc.edu.
Copyright © 1965 Julius Guccione

A STUDY OF THE CHANGES IN THE YOUNG RHESUS

MONKEY MANDIBLE FOLLOWING

CONDYLECTOMY

by

Julius M. Guccione, D.D.S.

A Thesis Submitted to the Faculty of the Graduate School

of Loyola University in Partial Fulfillment of

the Requirements for the Degree of

Master of Science

June

1965

Dedicated

to

My mother, Mrs. Julius M. Guccione, in appreciation for her many sacrifices which have made my education possible.

# LIFE

Julius M. Guccione was born in New Orleans, Louisiana, July 26, 1938. Having moved to California during his childhood, he was graduated from Mount Carmel High School, Los Angeles, June, 1956.

He attended the University of Southern California, Los Angeles, California, from September, 1956, to June, 1959, studying a pre-dental curriculum. In June, 1963, he was graduated from the Chicago College of Dental Surgery, Loyola University Dental School, Chicago, Illinois, with the degree of Doctor of Dental Surgery.

He is a member of Psi Omega Dental Fraternity and Omicron Kappa Upsilon Fraternity.

In June, 1963, he began graduate studies in the Department of Oral Biology of Loyola University, Chicago, Illinois. In June, 1964, he was appointed to a one year traineeship in the research training program sponsored by the National Institute of Health.

Upon completion of his graduate study he will begin an internship-residency program in Oral Surgery at Highland-Alameda County Hospital, Oakland, California.

## ACKNOWLEDGEMENTS

I wish to extend my gratitude to Dr. Nicholas C. Choukas, my advisor, for his invaluable guidance during this investigation.

To Drs. Patrick D. Toto and Nicholas Brescia, for their interest and constructive criticism in serving as members of my advisory board.

To Dr. Harry Sicher, director of the Research Training Program, under whose guidance my incentive for further study has been enhanced.

To my wife, Peggy Jane, who so generously gave her time for this study as my histology technician and also for her interest and encouragement.

In addition, my thanks to Franklin Boulevard Community Hospital for providing laboratory facilities and animals for this study, without which this work could not have been accomplished.

TABLE OF CONTENTS


| Chapter | | Page |
|---|---|---|
| I. | INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . | 1 |
| II. | REVIEW OF THE LITERATURE . . . . . . . . . . . . . . . . . | 2 |
| | A. Normal Growth of the Mandible . . . . . . . . . . . | 2 |
| | B. Normal Growth of the Rhesus Monkey Mandible . . . | 6 |
| | C. Experimental Condylar Injuries . . . . . . . . . . | 7 |
| III. | MATERIALS AND METHODS . . . . . . . . . . . . . . . . . . | 11 |
| | A. Animals . . . . . . . . . . . . . . . . . . . . . . | 11 |
| | B. Anesthesia . . . . . . . . . . . . . . . . . . . . | 11 |
| | C. Roentgenography . . . . . . . . . . . . . . . . . . | 12 |
| | D. Photography . . . . . . . . . . . . . . . . . . . . | 12 |
| | E. Impressions . . . . . . . . . . . . . . . . . . . . | 15 |
| | F. Preoperative Records . . . . . . . . . . . . . . . | 15 |
| | G. Surgical Procedure . . . . . . . . . . . . . . . . | 15 |
| | H. Postoperative Records . . . . . . . . . . . . . . . | 17 |
| | I. Sacrifice . . . . . . . . . . . . . . . . . . . . | 17 |
| | J. Histology . . . . . . . . . . . . . . . . . . . . | 18 |
| | K. Measurements . . . . . . . . . . . . . . . . . . . | 18 |
| IV. | FINDINGS . . . . . . . . . . . . . . . . . . . . . . . . | 21 |
| | A. Postoperative Findings . . . . . . . . . . . . . . | 21 |

| Chapter | | Page |
|---|---|---|
| | B. Post Mortem Findings | 22 |
| | C. Roentgenographic Findings | 36 |
| | D. Histologic Findings | 41 |
| V. | DISCUSSION | 49 |
| | A. Reformation of the Condyle | 49 |
| | B. Measurements | 51 |
| | C. Gonial Angle | 52 |
| | D. Dentition | 53 |
| VI. | SUMMARY AND CONCLUSIONS | 57 |
| | BIBLIOGRAPHY | 59 |
| | APPENDIX A | 65 |
| | APPENDIX B | 70 |

# CHAPTER I

## INTRODUCTION

The importance of the condyle as a growth center in the normal growth and development of the mandible and face has been well documented. Because of the close anatomic relation to man, the rhesus monkey has been included in previous mandibular studies. Studies of the mandibular condyle in rhesus monkeys have included: resection of the condyles and replacement by autogenous grafts; fracture dislocations of the condyle; and removal of the condyle.

The results of the few studies reported on the mandibular growth following condylectomies in the young rhesus monkey have been controversial. The latest studies reported by Walker (1960) showed almost complete reformation of the condyle, whereas in earlier studies the operated side remained stunted and deformed.

The purpose of this experimental study is to obtain information on the adjustive growth and development of the rhesus monkey mandible, specifically the repair process of bone. It is felt that this information may help more fully to understand the effects of such injuries, upon the growth and development of the mandible, when they occur in the young child. Furthermore such information may be used in the treatment plan of condylar injuries to prevent resultant facial deformities.

# CHAPTER II

## REVIEW OF THE LITERATURE

### Normal Growth of the Mandible

The studies pertaining to the growth of the mandible which have led to our present day concepts were made as early as the Eighteenth Century.

Following the publications by Belchier (1736) and Duhamel (1739) of the principle of vital staining by means of madder feeding, Hunter (1771) undertook the study of the mandible in madder (a dried and powdered root which upon fermentation stains newly formed bone salts red) fed pigs. He pointed out: (1) that the body of the mandible grows in height by growth of the alveolar bone; (2) that the jaw increases in all points until twelve months after birth when the six teeth are pretty well formed, but later, never increases in length between the symphysis and the sixth tooth; (3) that the deciduous second molar and then in succession the first, second, and third permanent molars seemed to erupt in the same relation to the mandibular ramus; (4) that the shedding or loss of teeth was always accompanied by the destruction of the alveolar process and that the eruption of teeth caused the growth of this structure; and (5) that the increase in length of this bone was provided by a deposit at the posterior border of the ramus, while the anterior or coronoid border was being resorbed to maintain proportion.

Studies were later undertaken by Tomes (1859) who described the growth of the mandible in post mortem specimens. Like Hunter he believed the growth to occur by apposition of bone on the posterior and anterior surfaces of the mandible. He described the posterior apposition as taking place at three points: (1) in the periosteum investing the coronoid process; (2) in the periosteum investing the angle; and (3) in the sub-articular cartilage of the condyle, which previously was mentioned and compared to the epiphyseal cartilage in children by Kolliker (1863) in his histologic studies.

Tomes also observed an angle formed by the borders of the body and ramus of the lower jaw and stated that this angle becomes more acute as growth continues.

Hunter's findings were confirmed, almost one hundred years later, by Humphry (1864) using the same experimental animal (the pig) but using metal wires instead of madder.

As Tomes did earlier, Cryer (1901) observed a decrease in obtuseness in the mandibular angles from birth until the permanent teeth are erupted, but he further observed that as the teeth are worn or extracted the alveolar process is resorbed and the horizontal planes of the jaws approach each other more closely and the angle again becomes obtuse.

A wedge-shaped (carrot shape) condylar cartilage (responsible for the forward and downward growth of the mandible) was described by Fawcett (1905), Low (1909), and Charles (1925) in the developing mandible of the foetus. Charles later (1934) referred to this wedge of cartilage as being a wedge of bone which has been formed with an intermediate chondroblast stage in contradistinction to the simple fibroblast bone differentiation of the rest of the mandible.

Hunter's work was again confirmed by Brash (1924) using the same experimental animal and conditions, and again later by Harris (1939) who claimed radiographic proof of the accuracy of their findings.

Brodie (1941), in radiographic studies using the cephalometer, emphasized the importance of the growth center in the mandibular condyle. He described the growth of the head of the condyle as being rapid and appearing to have a potential and mechanism of growth not unlike that of long bones, and this center is the last center in the head to cease activity. He considered the gonial angle or junction between body and ramus as remaining relatively stable in children at different ages and not becoming acute as reported in earlier literature. He explained this as a misunderstanding of the mandibular angle (the gonial angle compared by Brodie did not include the condyle as was previously described).

Sicher (1945) reported that there was a change in the mandibular angle and it had a definite significance. To avoid any further confusion he (1945, 1947) referred to the mandibular angle as the "condylar angle", and the angular region the "gonial angle". He showed that this change in the condylar angle is an indication of the relation of dentition to the mandibular joint, and further indicates that change in the mechanics of the mandibular joint and the muscles of mastication.

Rushton (1942) conducted a histologic study of condyles ranging from eight weeks postnatal to fifty-six years. He believed that:

> The mandibular condyle is a site of endochondral bone apposition in postnatal life until the end of the second decade when growth at this point normally ceases. The cartilage in which this bone arises is derived from a layer of precartilagenous connective tissue which lies beneath the fibrous articular surface and does not entirely disappear even in late mid-

dle age. At the end of the second decade the marrow cavity is separated from this layer by a complete closing plate of bone.

Sicher (1945) summarized the present day knowledge of mandibular growth and published his conclusions.

1) By the condylar growth the over-all length of the mandible increases, not however, the length of the mandibular body.
2) Appositional growth occurring along the entire posterior border of the ramus is the means of adjusting the width of the ramus and the length of the body to the growing height of the ramus.
3) Appositional growth at the tip and the upper borders of the coronoid process keeps pace with the heightening of the ramus, and resorption along the anterior border of the coronoid process and ramus corrects, at the same time, the antero-posterior dimension of the ramus and lengthens the alveolar space distally.
4) The growth of the mandibular body, measured from the lower border of the mandible to the free border of the alveolar process increases almost exclusively by apposition alone at the free borders of the alveolar process, growing into the space which is opened by the growth of the mandibular ramus in height.
5) In the condylar growth the growth of cartilage plays the leading role. It is the proliferation of the cartilage, and not its replacement by bone, which makes the mandible grow in height and over-all length, just as a long bone grows in length by proliferation of the epiphyseal cartilage.
6) Analogy between the hyaline cartilage in the mandibular condyle and the hyaline cartilage of the epiphyseal plate of the long bone does not exist. A cartilagenous epiphyseal plate of a long bone is interposed between the bony diaphysis and epiphysis. In the direction of the long axis of the long bone, this cartilage grows only interstitially. In contrast to this type of growth of an epiphyseal cartilage, the condylar cartilage of the mandible grows in all dimensions, at least partly by apposition.

In a study on the growth and form of the mandible Symons (1951) showed that a line joining the center of the head of the condyle to the inferior dental foramen does indicate fairly accurately the direction of bone growth. He referred to this line as a tract of bone formed by cartilage growth and replacement by bone. He connected this line with a line formed by the occlusal plane of the mandibular teeth and formed an angle which he believed to be relatively constant.

The influence of muscles on the mandibular growth has been suggested by some investigators. Experimental removal of various masticatory muscles in rats by Pratt (1943), Washburn (1946), Horowitz and Shapiro (1951, 1955), Watt and Williams (1951), and Avis (1961) showed some bone changes in the mandible.

Another group of investigators suggested a relationship between the form of the mandible and the occlusion of the teeth. Changes in the vertical dimension in the rabbit, monkey, and rat by Baker (1911); Breitner (1941); and Avant, Averill and Hahn (1952) produced some changes in the mandible.

## Normal Growth of the Rhesus Monkey Mandible

Few studies of mandibular growth in rhesus monkeys have been reported. Moore (1949) studied the head growth of the Macaca monkey using vital staining but did not mention the growth of the mandible.

Baume and Hooper (1951) studied biometrically and roentgenographically in forty-one rhesus monkeys the development of the mandible. The endochondral growth center at the condylar head proved to be the pacemaker and organizer of mandibular growth. Chondrogenesis proceeded in a dorsolateral direction with a very low vertical component, thus giving a relatively small increase in ramus height.

Appositional growth occurred on all surfaces. There was considerable growth at the anterior surface and lower border of the mandibular body contributing to the height and length. Vertical growth of the alveolar bone was evident in small amounts in the premolar region and none in the anterior region.

Apposition and resorption at the sites of muscle insertions were found to be performed by tendinous perimysia in place of distinct periosteum.

Osteogenic aplasia caused relatively stable regions at the mandibular canal below the second premolar. Superposing radiographs of this region was found useful in studies of growth.

## Experimental Condylar Injuries

Since the importance of the growth center in the mandibular condyle has been widely accepted, many investigators have experimentally interfered with this center to observe its effects on the growth of the jaw.

Sarnat and Engel (1951) performed unilateral and bilateral condylectomies in young rhesus monkeys, which resulted in no impaired masticatory function. After a postoperative survival period of four to seventeen months the findings revealed asymetrical changes in the unilateral and symetrical changes in the bilateral resected temporomandibular joint region of the animals. There was less growth in ramus height, some remodeling of the posterior border of the mandible, and a slight preangular notching. They noted that the coronoid process of the operated side was thicker and extended high above the zygomatic arch. The condylar stump lacked the growth potential and anatomical configuration of the normal.

Jarabak and Stuteville (1952) studied the effects of bilateral resection of the condyles in the monkey by serial roentgenograms and direct observation. They observed no facial changes after a postoperative period of six months. They reported an open bite in the incisor region, evidence of filling in of the articular fossa with a concavity formation along the anterior incline of the eminence of the temporal bone, increased antegonial notching and an acute mandibular angle.

Sarnat (1957), later, repeated his earlier experiment (1951) using the same animal (monkey) and procedure but including studies of facial and neurocranial changes during a longer postoperative survival period (twenty-five to thirty-five months.) His gross and roentgenographic findings of the mandible and temporomandibular joint areas in this group were similar to, but more accentuated than those of the previous group. Histologic studies of the unoperated side of one monkey revealed a normal joint and growing condyle, whereas the operated side revealed no disc interposed or evidence of cartilage being transformed to bone in the condylar area, but rather a layer of dense fibrous tissue which was attached to the ramus inferiorly and articulated with the temporal bone superiorly.

Tomek (1958) reported an experiment on the young rhesus monkey similar to that of Sarnat (1957) and confirmed the results reported by Sarnat and Engel (1951).

Walker (1960) in an experiment using young Macaca rhesus monkeys with fracture dislocated condyles, performed a unilateral condylectomy on one animal to serve as a predictable type. He reported a remarkable reformation of the condyle in the condylectomized monkey, the highest tip of which measured to the horizontal plane of the inferior border of the mandible revealed a greater distance than the unoperated side. He also showed that treatment by either the conservative or surgical method made no significant difference.

Herzberg and Sarnat (1962) roentgenographically compared the bony trabecular pattern in the mandible of young growing rhesus monkeys following condylectomies. They observed an alteration in the normal "N" pattern found in the ramus, which is formed by joining three axes: condylar-angular, condylar-retromolar, and coronoid-retromolar.

Regeneration of the mandibular condyle following resection has been reported in young rats. In 1951 Jarabak and Thompson reported no perceptable mandibular changes following bilateral condylar resection. However, in 1954 Jarabak observed that following condylar resection asymmetry occurred in some rats but not in others.

Jolly (1961) studied the tissue response to condylectomy in the region once occupied by the condyle in rats and observed a new articular process formation.

Lanfranchi (1955) resected mandibular condyles in young monkeys and replaced the missing growth centers with bone grafts from the femur in an attempt to abort the potential asymmetry. Although his results were inconclusive, he and Stuteville (1955) suggested further investigation and the use of a metatarsal bone growth center as a substitute for the damaged condylar growth center.

Kendrick and Cameron (1959) performed condylar resections in monkeys followed by transplantation of the distal head of the 5th metatarsal. Preliminary reports stated that epiphyseal growth occurred in the transplant of one unilaterally operated animal, but no epiphyseal growth occurred in the transplants of a bilaterally operated animal.

Heurlin, Gans, and Stuteville (1961) studied skeletal changes following fracture dislocation of the mandibular condyle in the adult rhesus monkey. Their findings were very similar to those changes observed in previous studies by Sarnat and Engel (1951) using young growing monkeys. They concluded:

> Since the skeletal changes observed in the adult animals in this study were similar to the changes observed in growing animals, one might question the importance placed on the loss of cartilagenous growth centers in

explaining these changes. Perhaps this growth center has been over emphasized when actually these changes may represent the result of anatomic loss of bone continuity, functional adaptation of bone, and muscle imbalance.

# CHAPTER III

## MATERIALS AND METHODS

### Animals

The animals used in this investigation were eight rhesus monkeys, obtained from Shamrock Farms, Inc., Middletown, New York. Five males and three females were used, and their weights ranged from three pounds to five and one-half pounds. Their exact ages were unobtainable, but were estimated from their weight and dentition to range approximately from four to six months of age. The animals were arbitrarily numbered one through eight.

Left unilateral condylectomies were performed on monkeys numbered one, three, and five. Bilateral condylectomies were performed on monkeys numbered two, four, and six. Monkeys numbered seven and eight were used as controls.

Postoperative survival periods ranged from four to eight months. Monkeys numbered one, two, and seven were sacrificed eight months after surgery; three, four, and eight at six months; and five and six were sacrificed at four months.

The animals were housed in stainless steel animal cages and were maintained on Rockland Primate Diet once a day, supplemented with a fresh fruit.

### Anesthesia

The anesthesia necessary in this investigation was obtained by injecting Nembutal Sodium (Abbott), 50 mg/cc concentration per five pounds of body weight, intravenously into the saphenous vein using a 25 gauge needle (Plate I). It was necessary in some instances, to supplement the original dose due to the variable reation of the monkeys to Nembutal.

## Roentgenography

A cephalostat was modified to accept the head of the monkey for lateral head roentgenographs (Plate II). This enabled the monkey to be placed in a supine position on an adjustable platform, with the head fixed at three points (right and left ear posts and a nasion positioning rod). An attempt was made to position the X-ray tube so the central beam passed directly through the ear posts. Eight by ten inch cassettes with intensifying screens were used. In order to conserve the amount of film used during each exposure, an eight by five inch lead shield was placed over one-half of the film. Eight by ten inch Kodak medical X-ray film (Blue Brand) was exposed by a dental X-ray unit manufactured by Ritter, set at 115 Kv. and 15 ma. for three-fourths of a second. A target film distance of thirty-nine inches was maintained.

Antero-posterior roentgenographs of the head were made with the monkey lying supine with the X-ray tube centered directly above the face.

Lateral and antero-posterior radiographs were taken on the surgical animals at the start of the investigation, immediately after surgery, at two month intervals postoperatively, and at the time of sacrifice. The control animals were roentgenographed at two month intervals and at the time of sacrifice.

## Photographs

Photographs of the procedures were taken with a Kodak Startech Camera,

FIGURE 1

Photograph of immobilized animal in a carrying cage ready for intravenous anesthesia.

FIGURE 2

Photograph of administration of Nembutal Sodium into saphenous vein.

PLATE I

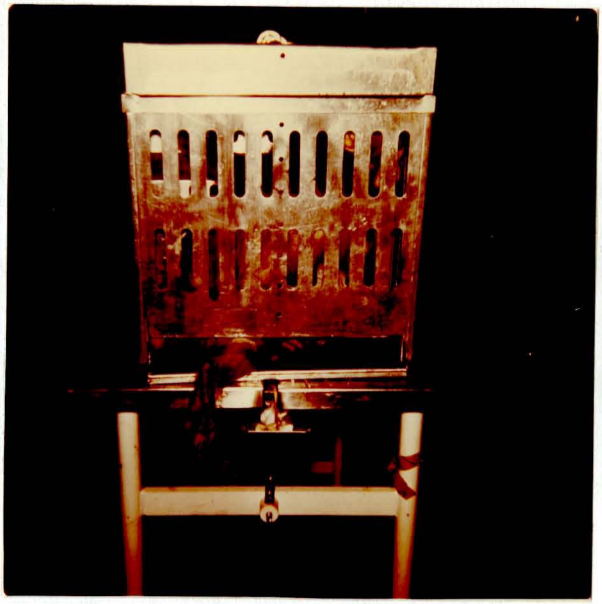

Figure 1

Figure 2

FIGURE 3

Photograph of modified cephalostat.

A. Ear post

B. Nasion positioning rod

C. 8 X 10 cassette holder

D. Adjustable platform to position monkey.

FIGURE 4

Photograph of animal positioned in cephalostat.



PLATE II

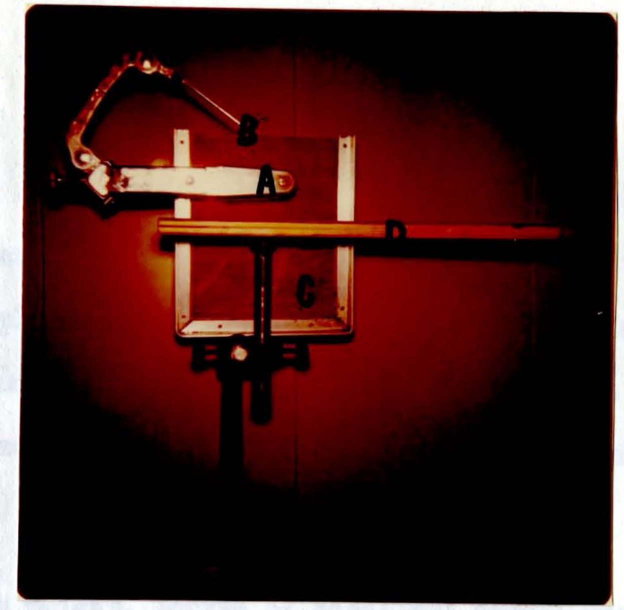


Figure 3

Figure 4

using Kodak 127 Ektachrome-X film with artificial light. Photomicrographs were taken with a 35 mm Zeis camera using Kodacolor-X film with a blue filter.

## Impressions

Impressions of the dental arches of all the monkeys were obtained by using Ontray Quick-cure Acrylic. The acrylic was allowed to set to the "doughy" stage and placed over the occlusal surfaces, while the monkey was anesthetized, and the jaw was closed until the acrylic was almost set. The acrylic bite was removed and stored for direct measurements.

## Preoperative Records

The monkey's weight, length of hand, and dental record including deviations from the normal were recorded (Table 1). Right and left lateral and antero-posterior roentgenographs were taken.

## Surgical Procedure

The head of each monkey was shaved, scrubbed with soap and water, and draped with sterile drapes. A strict sterile technique was maintained throughout the procedure.

A three centimeter vertical incision was made in the skin directly anterior to the auricular cartilage of the external ear. The parotid fascia and gland were reflected. By blunt dissection the capsule of the temporomandibular joint was exposed. A vertical incision was made through the capsule and periosteum to the bone, from the condyle along its neck to the ramus. The periosteum was reflected and a 700 tapered dental fissure bur was used to cut through the neck of the condyle just above the mandibular notch. The condyle

TABLE 1

PREOPERATIVE OBSERVATIONS

| Monkey no. | Sex | Weight in lbs. | Dentition | Midline of incisors | Length of hand in mm. | Estimated age in months | Surgery side | P. O. period in months |
|---|---|---|---|---|---|---|---|---|
| 1 | Female | 5.5 | All deciduous | Normal | 65.0 | 6 | Left | 8 |
| 2 | Female | 5.0 | All deciduous | Normal | 70.0 | 6 | Bilateral | 8 |
| 3 | Male | 5.0 | All deciduous | Normal | 70.0 | 6 | Left | 6 |
| 4 | Female | 5.0 | All deciduous | Normal | 70.0 | 6 | Bilateral | 6 |
| 5 | Male | 3.5 | All deciduous | Normal | 65.0 | 6 | Left | 4 |
| 6 | Female | 3.0 | All deciduous | Normal | 64.0 | 4 | Bilateral | 4 |
| 7 | Male | 4.5 | All deciduous | Normal | 65.0 | 4 | Control | 8 |
| 8 | Female | 5.0 | All deciduous | Normal | 70.0 | 5.5 | Control | 6 |

was shelled loose from the periosteum and articular disc with a periosteal elevator, detached from the lateral pterygoid muscle with a scalpel, and removed. The hemmorrhage was controlled. The deep tissues were closed with interrupted No. 000 plain catgut sutures and the skin with interrupted No. 000 black silk. Spray-On Plastic Bandage (Aeroplast) was applied over the wound and allowed to dry.

The mandible was not fixed to the maxilla in any way.

Prophylactic intramuscular injections of 600,000 units of long acting B-cillin (Wyeth) and 300,000 units of Wycillin (Wyeth) were given immediately after surgery.

Postoperative roentgenographs were taken, and the monkeys were placed in their cages upon regaining consciousness. They were allowed to remain on their previous diet with the addition of water to soften the food, and it was fed to them in this manner for three days. Each monkey was observed daily for any signs of infection, pain, or functional disability.

In performing the bilateral condylectomy, the surgical procedure on the opposite side was carried out in a similar manner.

## Postoperative Records

Every two months the monkeys were reanesthetized and weighed, length of hand, dental records, and antero-posterior roentgenographs were taken (Appendix B, 3-9).

## Sacrifice

Four to eight months postoperatively, the postoperative records were taken and the monkeys were sacrificed by injecting 3 cc of Nembutal (50 mg/cc) directly into the heart.

The heads were removed and dissected by removing the skin and fascia. The capsule of the temporomandibular joint was exposed and photographed. The heads were hemisected saggitally with a saw, and right and left roentgenographs were taken. The head was placed on the cassette, and the X-ray tube was centered over the external auditory meatus at a distance of thirty-six inches. The intensifying screens were removed and the machine set at 115 Kv. and 15 ma. for 4 seconds.

## Histology

Block sections of the temporomandibular joints of all the monkeys were removed with a diamond disc in a dental hand piece and placed in 10% formalin for forty-eight hours. The tissue blocks were decalcified in a 10% solution of formic acid (for approximately two weeks), washed for twelve hours in water, dehydrated with increasing concentrations of ethyl alcohol, cleared in chloroform, and infiltrated with and embedded in paraffin. Frontal sections were cut at six microns and stained with hematoxylin and eosin.

## Measurements

The mandibles were dissected free from the skull, and all soft tissue was removed for measurements.

The measurements made directly on the dry mandible included the height of the coronoid process, height and length of the mandibular body and width of the ramus. The mandible was placed in an upright position on a flat surface which was used as a reference point (Mandibular plane) when taking measurements (Plate III).

FIGURE 5

Photograph of lateral surface of mandible showing distances measured.

A. Height of coronoid process

B. Height of mandibular body

C. Length of Mandibular body

FIGURE 6

Photograph of medial surface of mandible showing measured width of the ramus.



PLATE III

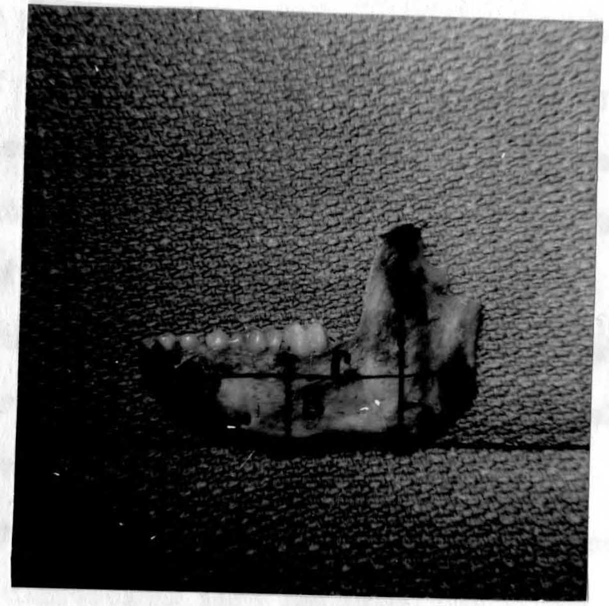

Figure 5

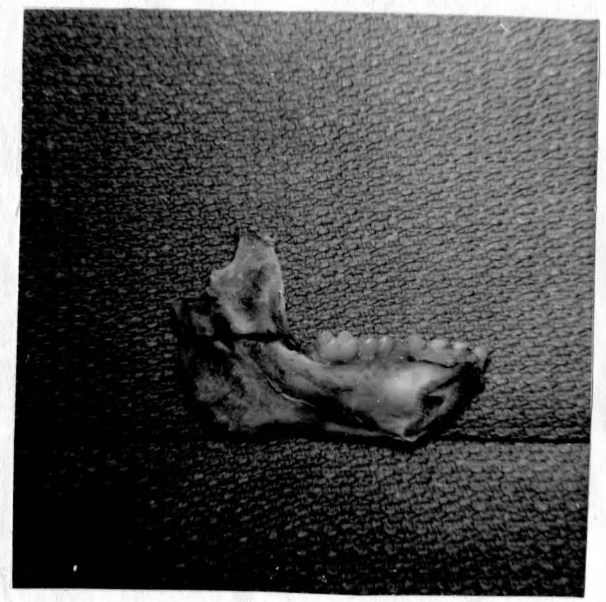

Figure 6

The height of the coronoid process was determined by measuring the distance of a line, perpendicular to the mandibular plane from the highest point on the coronoid process to the inferior border of the mandible.

The height of the mandibular body was determined by measuring the distance of a line, perpendicular to the "reference line" (Mandibular plane), from the highest point on the body just mesial to the first permanent molar to the inferior border of the mandible.

The ramus width was determined by measuring the distance between the posterior and anterior surfaces of the ramus on a line parallel to the mandibular plane at the level of the mandibular foramen.

The intermolar distances of the second deciduous and first permanent molars on the acrylic impressions were measured.

All measurements were recorded to a tenth of a millimeter.

# CHAPTER IV

# FINDINGS

## Postoperative Findings

All animals survived the surgical procedure, and showed no evidence of postoperative infection. There was no sign of facial nerve damage in any of the animals. Moderate edema was present in the surgical area the day after surgery and lasted 48 to 72 hours. The No. 000 silk sutures which remained in the skin after surgery were not present at the time of the first postoperative check.

The monkeys were able to masticate their normal diet within three days after surgery. No deviations of the mandible were observed during masticatory movements in any of the animals. The weight charts revealed a regular increase in weights of all animals (Appendix B, Tables 3-10).

None of the animals showed any sign of facial asymmetry.

The occlusion which remained normal in the control animals showed some signs of change in the operated animals. Animals numbered two (bilaterally operated) and three (left unilaterally operated) had deviations of 1 mm to the left as early as the second postoperative check at four months. The bilaterally operated animals numbered two, four, and six had open bites of 1 mm as early as the first postoperative check at two months (Appendix B, Tables 4, 6, and 8).

Throughout the postoperative periods of all the animals the deciduous dentition was present. Animal number two was the only animal that had a permanent incisor erupt during the postoperative period, at which time the deciduous incisors were still present. By the fourth month after surgery the first permanent molars were present in the oral cavity in all of the animals.

Impressions of the mandibular dental archs showed very little changes in the intermolar (permanent first and deciduous second molars) distances. The intermolar distances did not vary more than .3 mm in any of the animals from the time of surgery until sacrifice (Appendix B, Tables 3-10).

The antero-posterior postoperative roentgenographs taken at two month intervals of the control animals revealed symmetry of the facial skeleton. In the condylar region a typical growing condyle was observed; the condyle appeared to increase in over all size and maintained the normal morphology.

Antero-posterior postoperative roentgenographs taken at two month intervals of all of the operated animals revealed a bony reformation on the operated side. At two months the roentgenographs showed a structure shaped like a normal condyle, although it was not as high, radiopaque, or as large as the normal control. By the fourth postoperative month this structure attained a radiopacity and shape comparable to a normal condyle but lacked the normal condylar height. This structure continued to show an increase in size, maintaining a normal shape and radiopacity from the fourth through the eighth postoperative months, but never attained the normal condylar height (Plates IV-IX).

## Post Mortem Findings

FIGURE 7

Photograph of antero-posterior roentgenograph of animal No. 1 immediately after surgery. (Left condylectomy)

FIGURE 8

Photograph of modified antero-posterior roentgenograph of animal No. 1, eight months after surgery.



PLATE IV

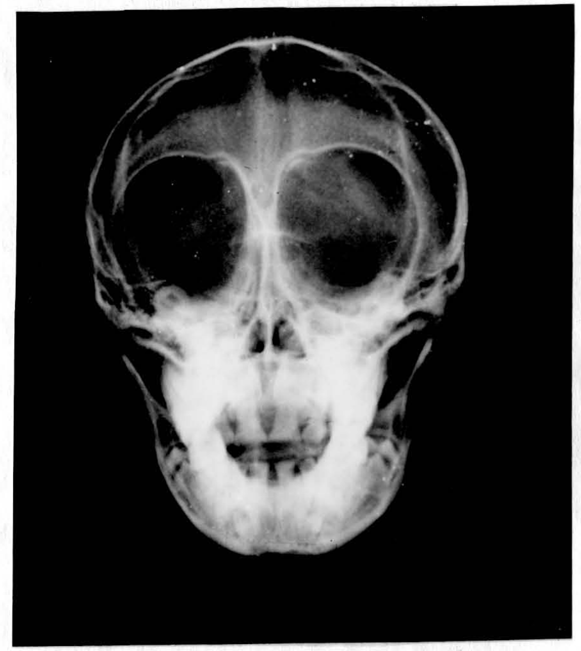

Figure 7

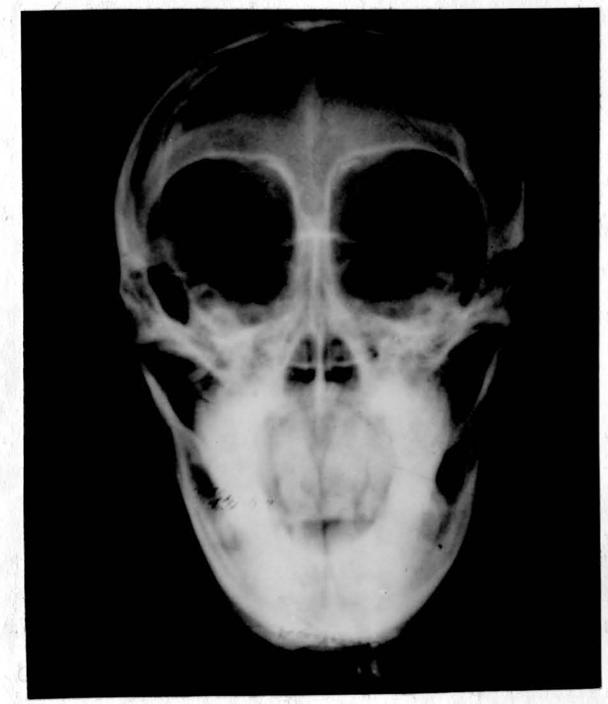

Figure 8

FIGURE 9

Photograph of antero-posterior roentgenograph of animal No. 2 immediately after surgery. (Bilateral condylectomy)

FIGURE 10

Photograph of modified antero-posterior roentgenograph of animal No. 2, eight months after surgery.



PLATE V

Figure 9

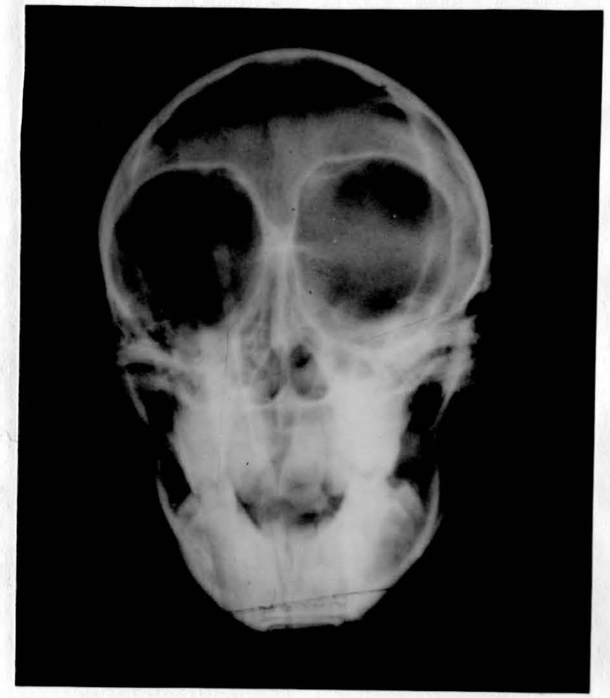

Figure 10

FIGURE 11

Photograph of antero-posterior roentgenograph of animal No. 3 immediately after surgery. (Left condylectomy)

FIGURE 12

Photograph of modified antero-posterior roentgenograph of animal No. 3, six months after surgery.



PLATE VI

Figure 11

Figure 12

FIGURE 13

Photograph of antero-posterior roentgenograph of animal No. 4 immediately after surgery. (Bilateral condylectomy)

FIGURE 14

Photograph of modified antero-posterior roentgenograph of animal No. 4, six months after surgery.



PLATE VII

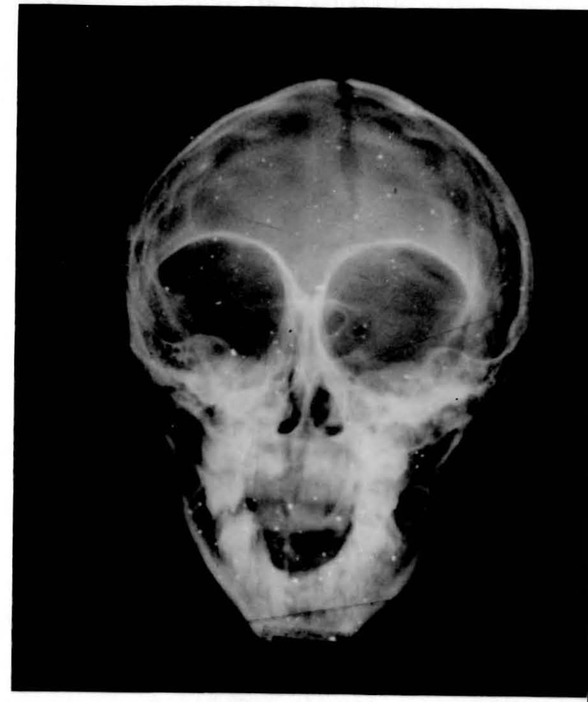

Figure 13

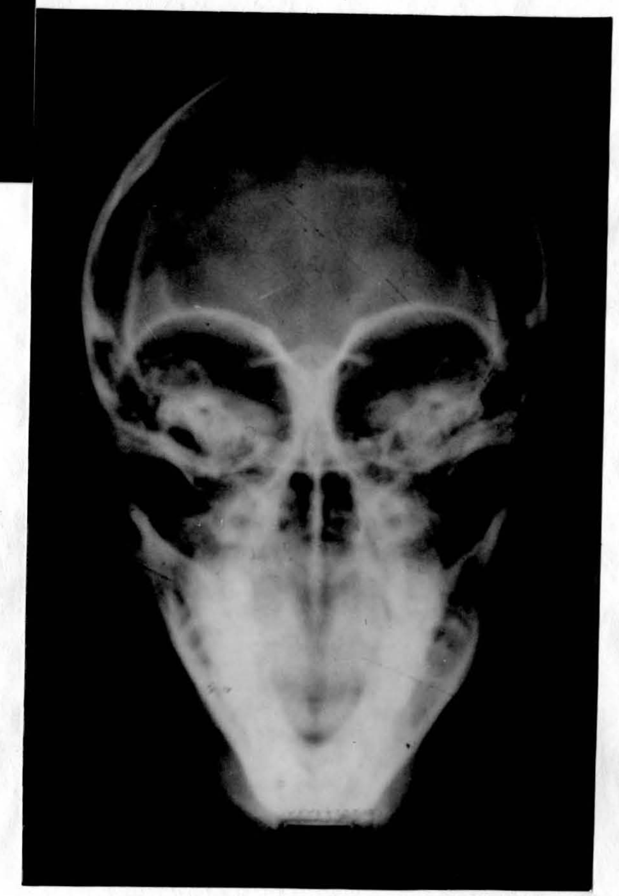

Figure 14

FIGURE 15

Photograph of antero-posterior roentgenograph of animal No. 5 immediately after surgery. (Left condylectomy)

FIGURE 16

Photograph of modified antero-posterior roentgenograph of animal No. 5, four months after surgery.



PLATE VIII

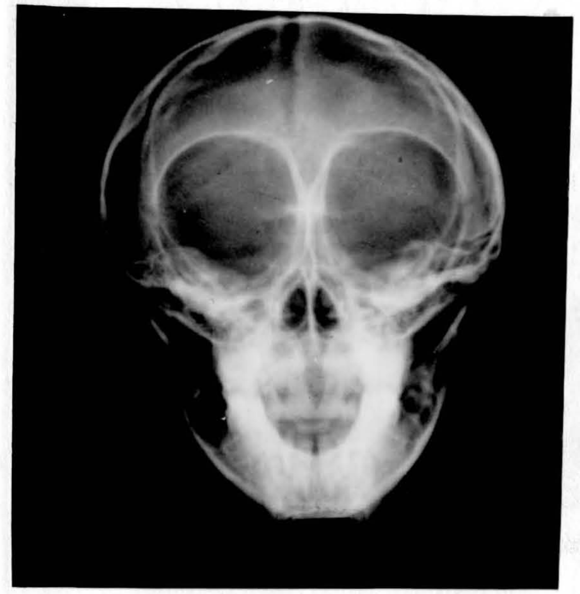

Figure 15

Figure 16

FIGURE 17

Photograph of antero-posterior roentgenograph of animal No. 6 immediately after surgery. (Bilateral condylectomy)

FIGURE 18

Photograph of modified antero-posterior roentgenograph of animal No. 6, four months after surgery.



PLATE IX

Figure 17

Figure 18

## Gross Findings

### Control animals

Temporomandibular joint area.--Animals numbered seven and eight showed evidence of a thin fibrous capsule covering the joint area. This fibrous covering was attached to the temporal bone at the anterior, medial, and lateral boundaries of the articular tubercle and fossa. The capsule was thickest at the lateral boundary, which formed the temporomandibular ligament. This ligament originated from the zygomatic process of the temporal bone and attached to the neck of the mandibular condyle.

The lateral pole of the condyle was palpated and was found to be within the lateral border of the zygomatic process of the temporal bone. The posterior boundary of the condyle was just in front of the postglenoid process of the temporal bone and was separated from it by the thin fibrous capsule covering the condyle.

The mandible was opened manually and the joint area was observed. The condyle rotated and glided in a downward and forward direction when the jaw was opened. In the open position of the jaw the lateral and posterior boundaries of the fibrous capsule slackened.

The ramus.--The ramus extended upward from the posterior boundary of the mandibular body and ended in two processes: the anterior coronoid process and the posterior condyloid process. The ramus was situated laterally to the plane of the alveolar process in the molar region. The thickness of the ramus was relatively thinner than the body of the mandible. The thickest portion of the ramus extended from the condyle to the mandibular canal.

Measurements of the ramus width at the level of the mandibular canal did not differ more than .5 mm between the right and left sides and not more than 1.1 mm between the two control animals (Table 2).

The coronoid process.--The coronoid process extended upward from the anterior border of the ramus and was shaped like a triangle, ending in a sharp fin-like apex. The posterior border was concave and the anterior border convex. The lateral and medial surfaces were small. The apex of this process extended above the level of the condyloid process and the surface was rough.

The coronoid process was very thin compared to the rest of the mandible; the thickest portion was along the anterior border.

Measurement of the height of the coronoid process showed a difference of .2 mm between the right and left side and a difference of 2.4 mm between the two control animals (Table 2).

The gonial angle.--This area joined the posterior border of the ramus with the inferior border of the body. The outer and inner surfaces were irregularly rough. The postero-inferior border of the gonial angle was convex.

An antegonial notch was not observed in these animals.

The mandibular body.--The body of the mandible was horseshoe shaped and carried the alveolar process. The surface of the body was generally smooth with the exception of a sharply elevated tubercle in the inferior lingual area of the midline. Two to three foramina were observed just above the inferior border below the right and left deciduous molars.

Measurements of the lengths of the mandibular body, comparing the

TABLE 2

POST MORTEM MEASUREMENTS (mm)

| Monkey No. and Side of Surgery | P.O. Period in Months | Mandibular Body Length Right-Left | | Mandibular Body Height Right-Left | | Ramus Width Right-Left | | Coronoid Process Right-Left | | Intermolar Distance (Deciduous) | Intermolar Distance (Permanent) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Left | 8 | 56.2 | 56.4 | 15.0 | 15.0 | 21.1 | 21.2 | 36.6 | 36.2 | 16.2 | 17.5 |
| 2 Bilateral | 8 | 56.5 | 56.0 | 14.9 | 14.5 | 21.0 | 21.0 | 35.0 | 35.1 | 15.8 | 17.2 |
| 3 Left | 6 | 55.0 | 55.0 | 14.5 | 14.5 | 20.0 | 20.2 | 36.9 | 37.8 | 16.9 | 17.9 |
| 4 Bilateral | 6 | 53.5 | 53.5 | 14.8 | 15.1 | 21.1 | 21.0 | 35.0 | 34.7 | 16.1 | 16.2 |
| 5 Left | 4 | 49.0 | 49.2 | 13.0 | 13.4 | 19.5 | 19.3 | 33.0 | 32.1 | 14.3 | 15.4 |
| 6 Bilateral | 4 | 47.3 | 47.5 | 13.2 | 13.3 | 17.0 | 17.2 | 31.0 | 31.2 | 15.4 | 16.9 |
| 7 Control | 8 | 54.8 | 54.0 | 13.3 | 14.0 | 21.2 | 21.6 | 34.9 | 34.8 | 17.1 | 18.9 |
| 8 Control | 6 | 54.5 | 54.5 | 16.1 | 16.0 | 21.0 | 20.5 | 37.0 | 37.2 | 14.9 | 15.8 |

right and left halves, did not differ more than .8 mm. This measurement on the control animal did not differ more than .5 mm with the other control animal (Table 2).

The dentition.--There were no malposed teeth in these animals. There were no signs of mandibular deviation or open bites.

The deciduous dentition was still present and the first permanent molars were erupted.

Unilaterally operated animals

Temporomandibular joint area.--Right and left condylar regions of all of these animals showed evidence of a distinct fibrous capsule comparable to the control animals. The condyle on the unoperated side was in the same position as that of the operated side and the control animals.

The position of the new articular head on the operated side was slightly anterior and inferior as compared to that of the opposite side and control animals.

The lateral poles of the new articular heads when palpated were the same as the unoperated side and control animals with the exception of animal number three, which projected more laterally and anteriorly.

The right and left temporomandibular joints of the three unilaterally operated animals showed freedom of movement when the jaws were manually opened and closed.

The ramus.--The shape and thickness of the mandibular ramus was similar to that of the unoperated side and of the control animals. Measurements of the ramus width at the level of the mandibular canal, comparing the operated side with the unoperated side, did not differ more than .2 mm and were not consistent as to the side of surgery. The measurement when compared with the control of its group did not differ more than .5 mm (Table 2).

The coronoid process.--The shape and thickness of the coronoid process on the operated side in these animals revealed no observable differences from the unoperated side or the controls. The measurements of the coronoid process height did not differ more than .9 mm from the unoperated side and not more than .7 mm from the control of its group. This difference was not consistent with the side of surgery (Table 2).

The gonial angle.--There were very little observable differences in the gonial angles of the operated sides compared with the unoperated sides or the control animals other than a slight increase in acuteness on the operated side. Animal number three had a slight antegonial notch of 1 mm on the operated side compared to the unoperated side (Plate XII, Figure 27).

The mandibular body.--The shape and thickness of the mandibular body of these animals were similar to the control animal of its group. The length of the mandibular body showed a difference of not more than .2 mm between the operated and unoperated side. This length compared with the control of its group showed a difference of 2.4 mm (Table 2).

The height of the mandibular body in the first molar region did not differ more than .4 mm from the unoperated side and 1.7 mm from the control of its group. All of these measurements were not consistent with the side of surgery (Table 2).

SCHOOL OF
LOYOLA
UNIVERSITY
LIBRARY
DENTISTRY

<u>The dentition</u>.--Dental observations revealed no malposition or disturbed eruption of teeth in any of these animals. A mandibular deviation was observed in only one of these animals. Animal number three had a deviation of 1 mm to the left. There was no sign of an open bite in the incisor region in any of these animals.

## Bilaterally operated animals

<u>Temporomandibular joint area</u>.--All of these animals showed evidence of a distinct fibrous capsule comparable to the control animals. The positions of the new articular heads on these animals, with the exception of animal number six, were slightly anterior and inferior as compared to the control animals. The left articular head and neck of animal number six inclined distally at an angle of forty-five degrees to the posterior border of the ramus, considerably more than the other operated side.

The lateral poles of the new articular heads when palpated were the same when compared with those of the control animals.

All of the temporomandibular joints of the three bilaterally operated animals showed freedom of movement when the jaws were manually opened and closed.

<u>The ramus</u>.--The shape and thickness of the mandibular ramus were similar to those of the control animals.

The measurements comparing the right and left ramus widths at the level of the mandibular canal in these animals did not differ more than .2 mm. These widths when compared to the widths of the control animal in its group did not differ more than .6 mm. These differences were not consistent with the side of surgery (Table 2).

The coronoid process.--The shape and thickness of the right and left coronoid processes in each of these animals revealed no observable differences from the control animals.

The bilateral coronoid height measurement did not differ more than .3 mm from each other and not more than 2.5 mm from the control of its group. These differences were not consistent as to the side of surgery (Table 2).

The gonial angle.--The gonial angle in these animals showed bilateral symmetry and slight increase in acuteness when compared with their control animals.

Animals numbered two and four had bilateral antegonial notching of 2 mm (Plates XI, XII).

The mandibular body.--The lengths of the mandibular body in the right and left sides of these animals did not differ more than .5 mm. These lengths compared with the control animal of its group showed differences of 2 mm (Table 2).

The height of the mandibular body in the first molar region did not differ more than .4 mm between the right and left sides. This height compared with the control animal of its group did not differ more than 1.7 mm (Table 2). These differences were not consistent with the side of surgery.

The dentition.--Dental observations revealed no malposition or disturbed eruption of teeth in any of these animals. All of these animals had open bites in the incisor region of at least 1 mm (Appendix B, Tables 4, 6, and 8).

One of these animals (number 2) had a deviation of 1 mm to the left of the midline.

## Roentgenographic Findings

### Control animals

Lateral head roentgenographs of the hemisected skulls showed a condylar process within the articular fossa. In observing the profile of the condyle the head was forced upward and forward so that the neck appeared to be bent forward (Plate X).

The trabecular pattern of bone in the ramus of these animals showed the classical "N" pattern of bone mentioned by Herzberg and Sarnat (1952). Three trajectories of bone were observed in the ramus: one extending from the condyle to the angle, one extending from the condyle to the retro-molar area, and one from the coronoid process to the retro-molar area (Plate X).

### Unilaterally operated animals

Lateral head roentgenographs of the hemisected skulls showed a reformation of an articular process. Animals numbered one and three showed remarkable reformation of this process to an almost normal profile, (forward bending of the condylar neck). The condylar necks of these two animals appeared shorter than the unoperated side (Plates XI, XII). Animal number five appeared to have this short condylar neck with a reformation lacking the typical profile of a normal condyle, (Plate XIII).

The trabecular pattern of bone in the ramus of these animals maintained the classical "N" pattern of bone, observed in the control animals, and

FIGURE 19

Photograph of post mortem left lateral head roentgenograph of animal No. 7. (Control)

FIGURE 20

Photograph of post mortem right lateral head roentgenograph of animal No. 7. (Control)

FIGURE 21

Photograph of post mortem left lateral head roentgenograph of animal No. 8. (Control)

FIGURE 22

Photograph of post mortem right lateral head roentgenograph of animal No. 8. (Control)



PLATE X

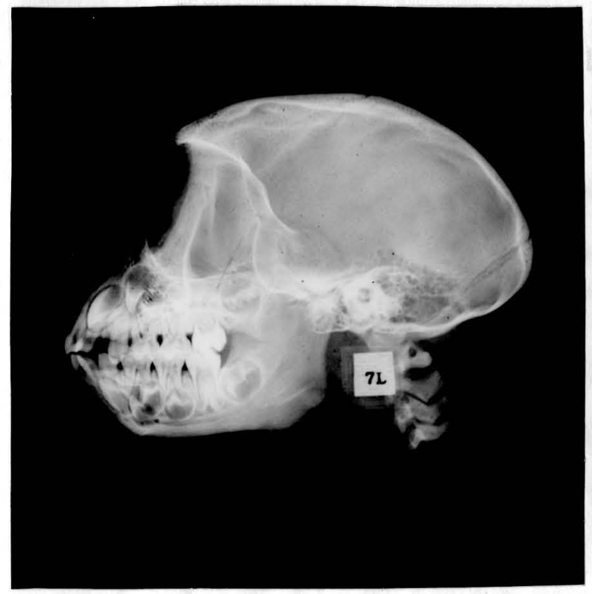


Figure 19


Figure 20

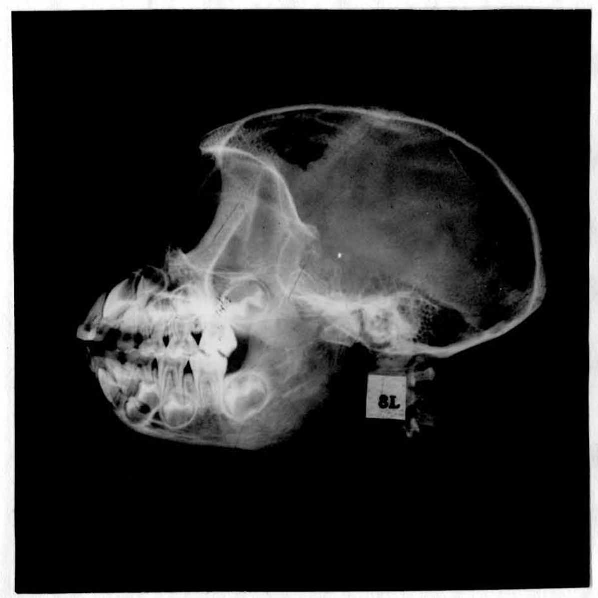


Figure 21

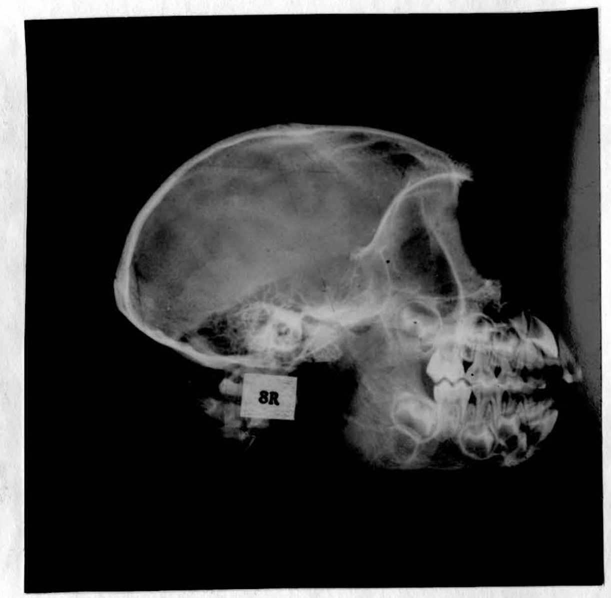


Figure 22

FIGURE 23

Photograph of post mortem left lateral head roentgenograph of animal No. 1. (Left condylectomy)

FIGURE 24

Photograph of post mortem right lateral head roentgenograph of animal No. 1. (Left condylectomy)

FIGURE 25

Photograph of post mortem left lateral head roentgenograph of animal No. 2. (Bilateral condylectomy)

FIGURE 26

Photograph of post mortem right lateral head roentgenograph of animal No. 2. (Bilateral condylectomy)



PLATE XI


Figure 23


Figure 24

Figure 25


Figure 26

FIGURE 27

Photograph of post mortem left lateral head roentgenograph of animal No. 3. (Left condylectomy)

FIGURE 28

Photograph of post mortem right lateral head roentgenograph of animal No. 3. (Left condylectomy)

FIGURE 29

Photograph of post mortem left lateral head roentgenograph of animal No. 4. (Bilateral condylectomy)

FIGURE 30

Photograph of post mortem right lateral head roentgenograph of animal No. 4. (Bilateral condylectomy)



PLATE XII

Figure 27


Figure 28

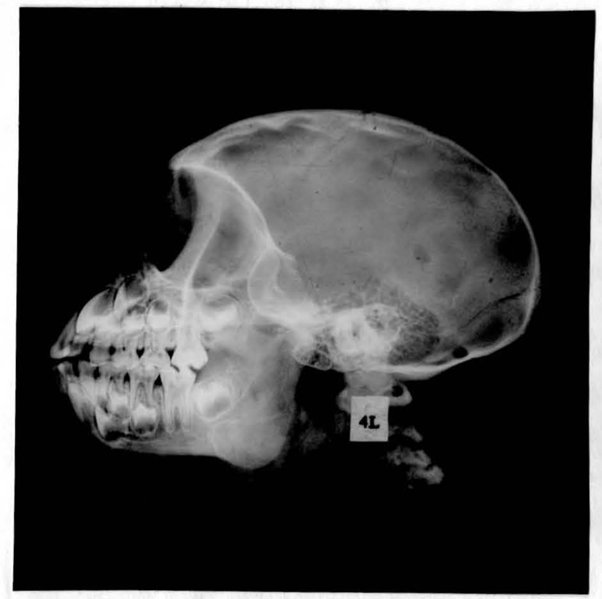


Figure 29


Figure 30

FIGURE 31

Photograph of post mortem left lateral head roentgenograph of animal No. 5. (Left condylectomy)

FIGURE 32

Photograph of post mortem right lateral head roentgenograph of animal No. 5. (Left condylectomy)

FIGURE 33

Photograph of post mortem left lateral head roentgenograph of animal No. 6. (Bilateral condylectomy)

FIGURE 34

Photograph of post mortem right lateral head roentgenograph of animal No. 6. (Bilateral condylectomy)



PLATE XIII


Figure 31


Figure 32

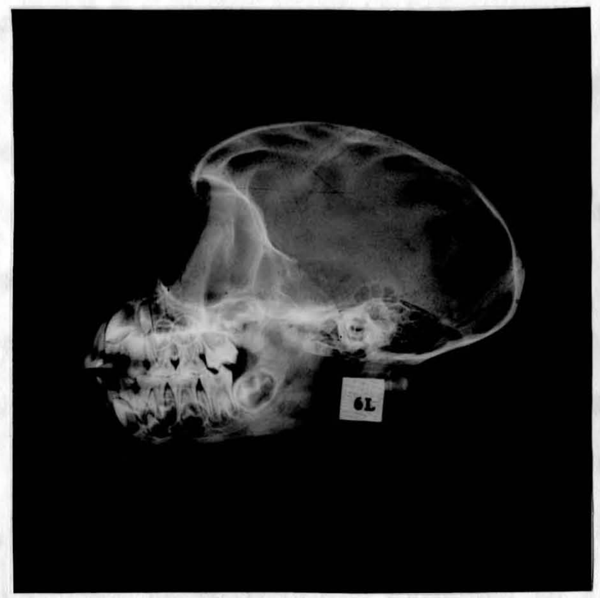


Figure 33


Figure 34

converged toward the new articular area (plates X-XIII).

Bilaterally operated animals

Lateral head roentgenographs of the hemisected skulls showed reformation of an articular process all of which lacked the normal condylar neck height and normal profile of the control animals and the unilaterally operated animals.

The trabecular pattern of bone in the ramus of these animals followed the same classical "N" pattern which was found in the control and unilaterally operated animals.

## Histologic Findings

Control animals

Histologic findings of the temporomandibular joint of control animals numbered seven and eight revealed a joint comparable to the normal temporomandibular joint.

There was a diarthrosis between the mandibular condyle and temporal bone with a fibrous disc between these articulating bodies.

The articulating surface of the temporal bone consisted of a thin compact bone in the fossa area and spongy bone covered with a thin layer of compact bone in the area of the articular tubercle. The articulating surface of this bone was covered by a fibrous layer containing cartilage cells.

The condyle of the mandible was compased of cancellous bone covered by a thin layer of compact bone. The marrow spaces were filled with myeloid tissue. The periosteum was attached to the compact bone along the neck of the condyle and extended superiorly and joined the articular fibrous covering of

FIGURE 35

Photomicrograph, 22.5X, of condyle in animal No. 7. (Control)

A. Fibrous covering

B. Hyalin cartilage

C. Bone marrow

D. Cartilage islands

FIGURE 36

Photomicrograph, 22.5X, of condyle in animal No. 8. (Control)

A. Articular disc

B. Inferior articular space

C. Fibrous covering

D. Hyalin cartilage

E. Bone marrow

F. Cartilage islands



PLATE XIV

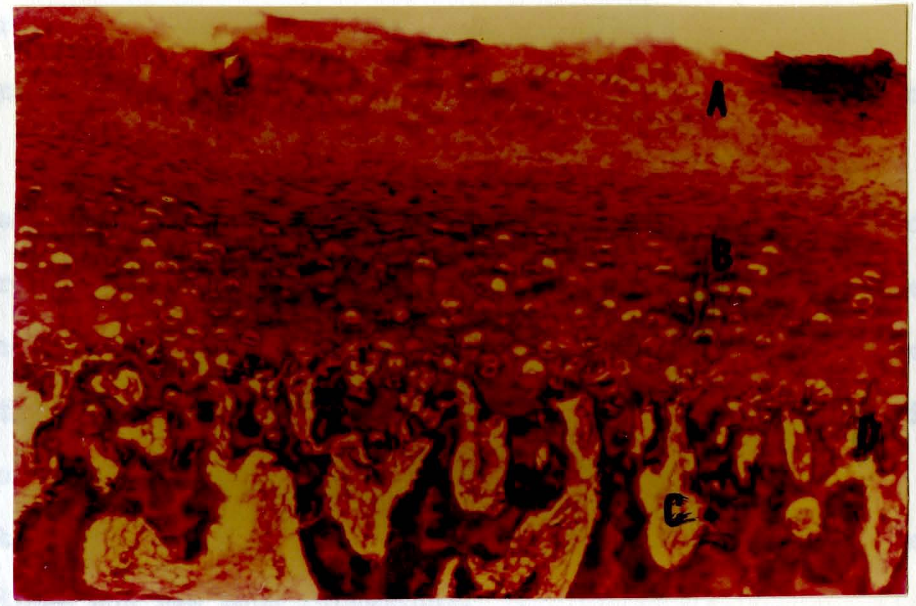


Figure 35

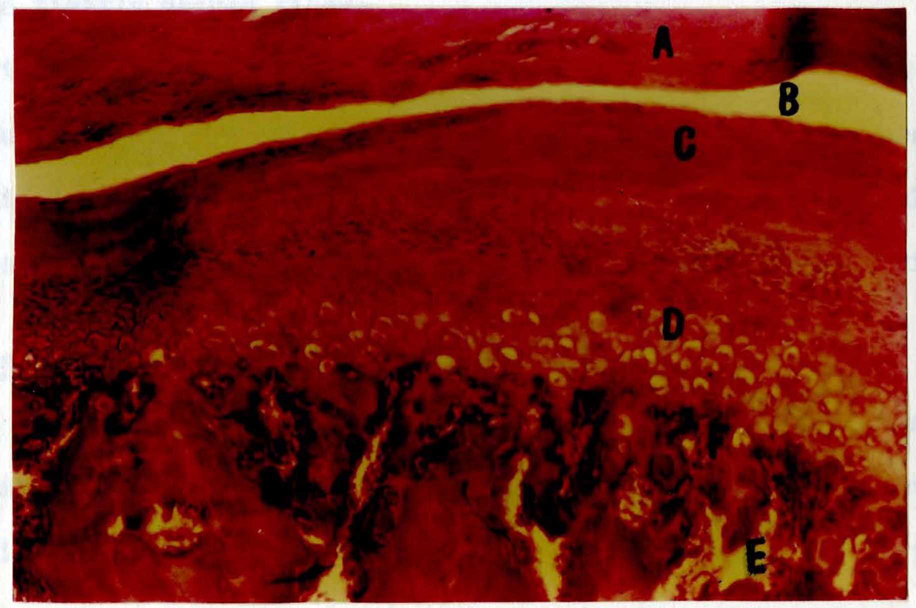


Figure 36

the condylar head.

A fibrous covering on the condyle was composed of a network of collagenous fibers in the superficial layer and deep staining fibroblasts and chondrocytes containing few collagenous fibers in the deeper layer (transitional layer).

Beneath the fibrous covering a hyaline cartilage was observed. Numerous chondrocytes were observed in the outer layer of this cartilage (proliferating cartilage). In the deeper layer the chondrocytes were greatly enlarged and the intercellular substance was deeply stained (degeneration and calcification of cartilage). The deep layer of the cartilage joined the bone marrow and trabecular bone within the head of the condyle (resorption of calcified cartilage and new bone formation).

The articular disc separated the joint space into a superior and inferior articular space. The disc was composed of dense fibrous tissue with straight and tightly packed fibers.

On the lateral surface of the joint an articular capsule was present and consisted of an outer fibrous layer and an inner layer of thin connective tissue. This inner layer contained numerous blood vessels, with small finger-like processes and folds (synovia) protruding into the articular cavity.

<u>Four month specimens</u>

All of the temporomandibular joint specimens from animals numbered five (unilaterally operated) and six (bilaterally operated) showed evidence of a diarthrodial joint enclosed by an articular capsule comparable to the control animal.

Both animals had a fibrocartilage on the new articular process of the

FIGURE 37

Photomicrograph, 22.5X, of condyle in animal No. 5, four months after surgery showing same structures found in normal controls.

FIGURE 38

Photomicrograph, 22.5X, of condyle in animal No. 6, four months after surgery showing same structures found in normal controls.



PLATE XV

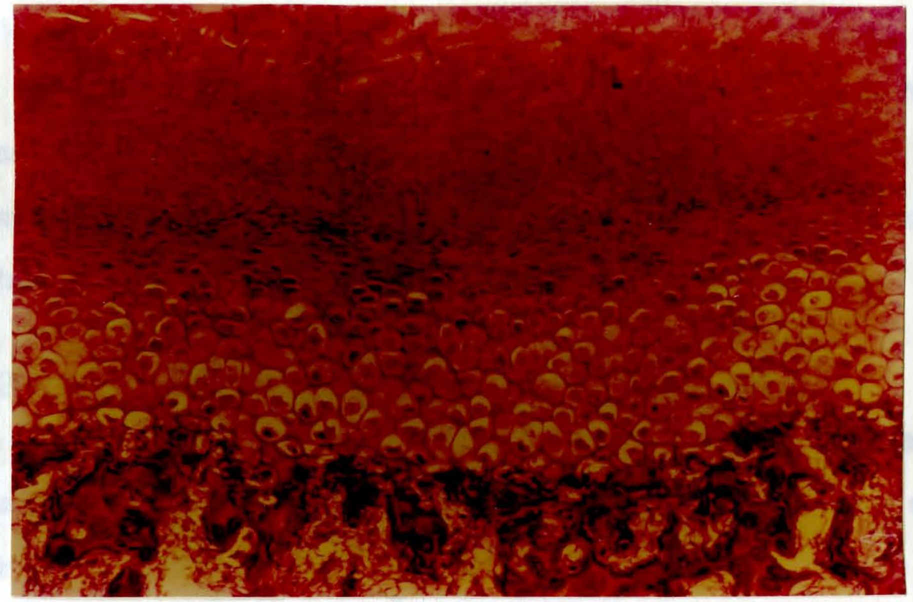

Figure 37

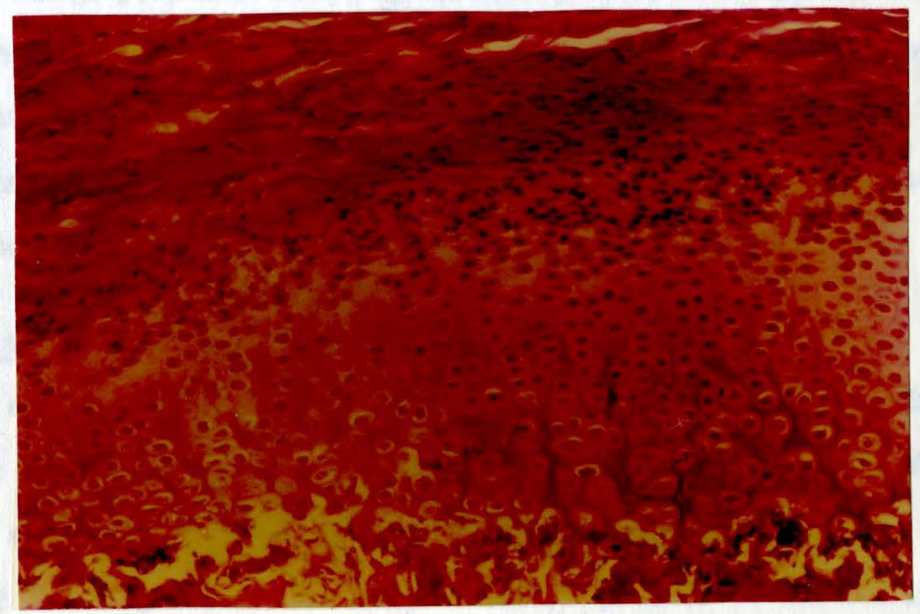

Figure 38

mandible. The zones of cartilage proliferation, degeneration, calcification, and resorption and bone formation present in the control animals were observed in these two animals (Plate XV).

The temporal bones in these animals were covered with a fibrous layer containing cartilage cells.

An articular disc with a superior and inferior articular space was present in both animals.

Six month specimens

All of the temporomandibular joint specimens from animals numbered three (unilaterally operated) and four (bilaterally operated) showed evidence of a diarthrodeal joint enclosed by an articular capsule, comparable to the control animals.

Fibrocartilage covered the new articular process of the mandible. The zones of cartilage proliferation, degeneration, calcification, and resorption and bone formation present in the control animals were observed in these two animals (Plate XVI).

An articular disc with a superior and inferior articular space was present in both animals.

Eight month specimens

All of the temporomandibular joints in the specimens from animals numbered one (unilaterally operated) and two (bilaterally operated) showed evidence of a diarthrodeal joint enclosed by an articular capsule.

Fibrocartilage covered the new articular process of the mandible. The zones of cartilage proliferation, degeneration, calcification, and resorption

FIGURE 39

Photomicrograph, 22.5X, of condyle in animal No. 3, six months after surgery showing same structures found in normal controls.

FIGURE 40

Photomicrograph, 22.5X, of condyle in animal No. 4, six months after surgery showing same structures found in normal controls.



PLATE XVI

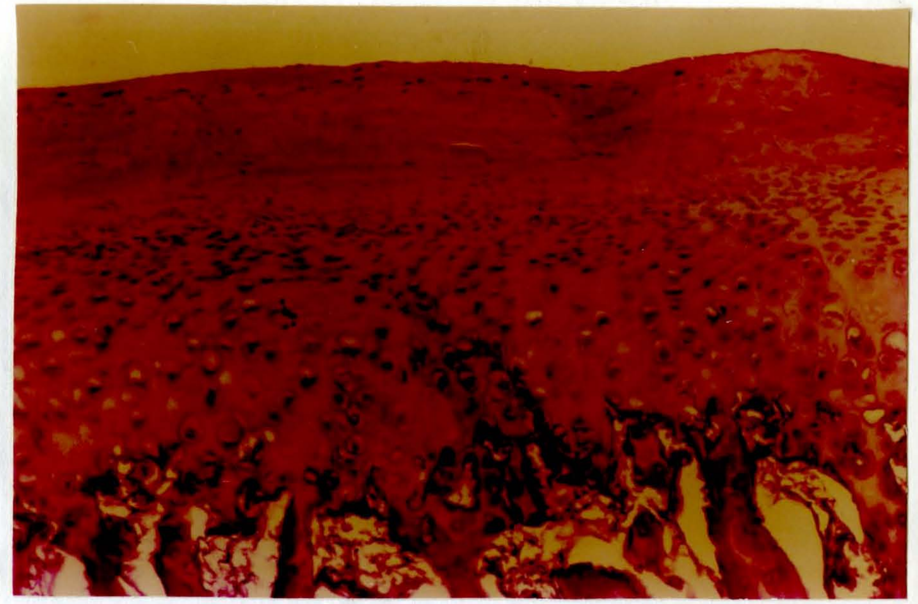

Figure 39

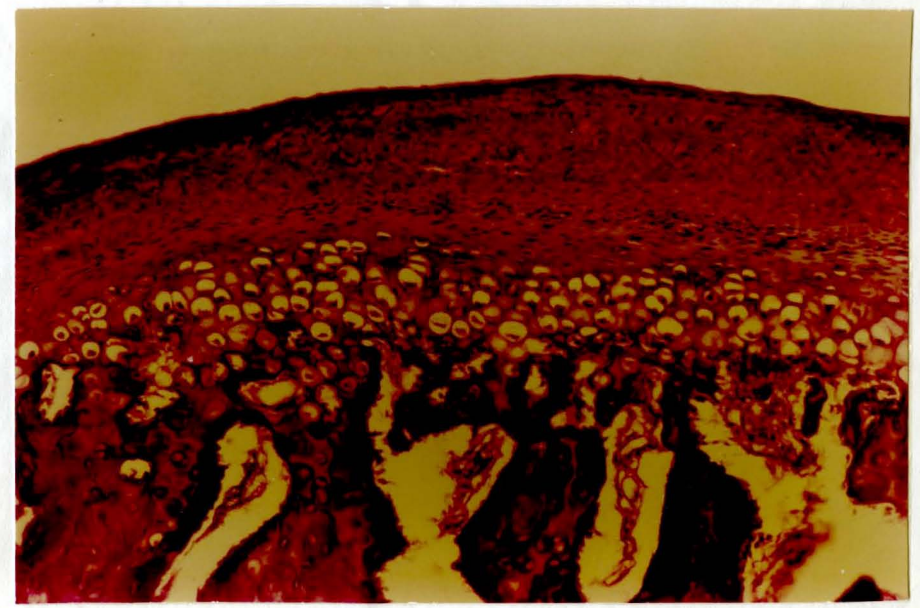

Figure 40

FIGURE 41

Photomicrograph, 22.5X, of condyle in animal No. 1, eight months after surgery showing same structures found in normal controls.

FIGURE 42

Photomicrograph, 22.5X, of condyle in animal No. 2, eight months after surgery showing same structures found in normal controls.



PLATE XVII

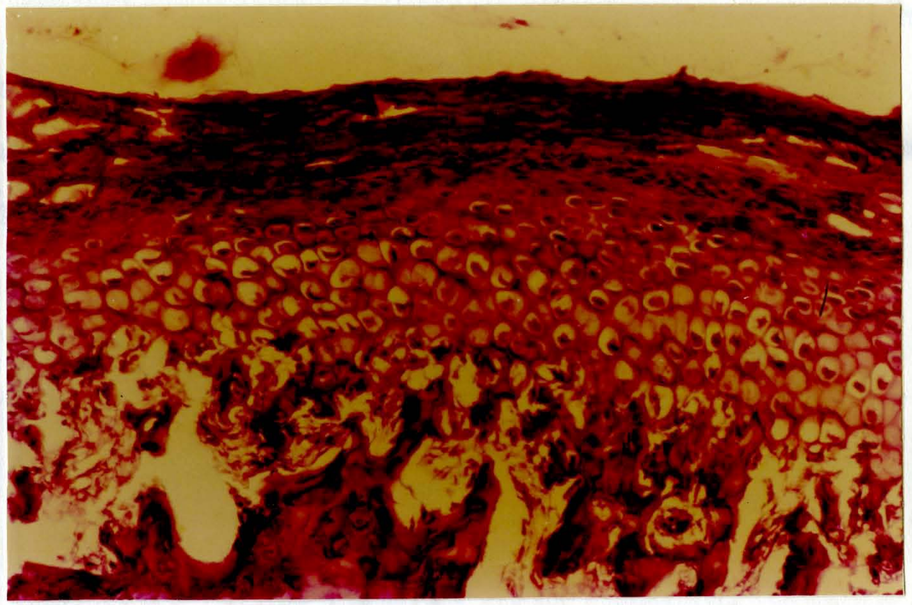

Figure 41

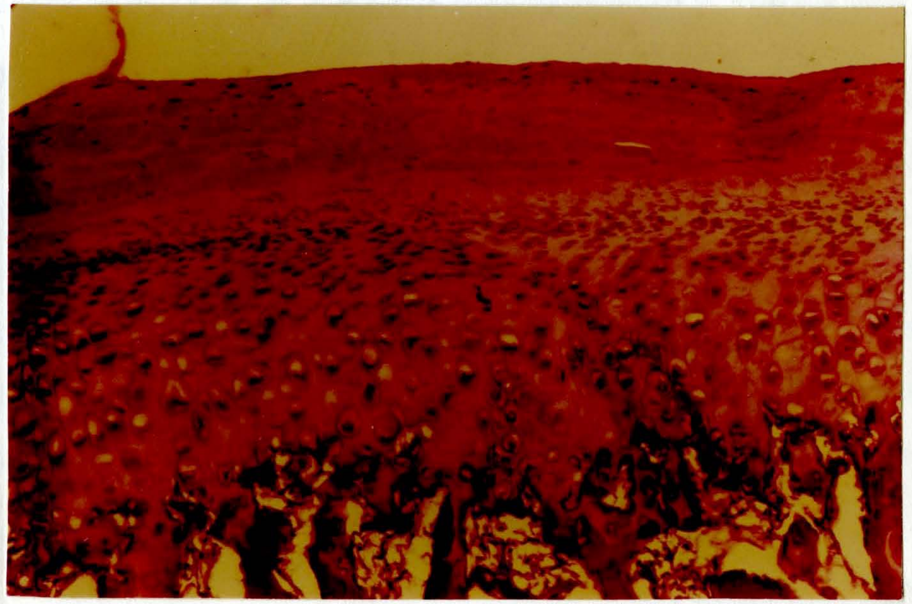

Figure 42

and bone formation present in the control animals were observed in these two animals, (Plate XVII).

The temporal bones in these animals were covered with a fibrous layer containing cartilage cells.

An articular disc with a superior and inferior articular space was present in both animals.

# CHAPTER V

# DISCUSSION

## Reformation of the Condyle

A complete reconstruction and function of the condyle four months after condylectomy was observed in this study. The process of condylar reformation was not observed in this study, or does the literature describe the process in monkeys.

The process of reformation is probably similar to the healing of a bone fracture as described by Weinmann and Sicher (1955) with some variations. When the condyle is removed surgically, blood vessels are ruptured from the most superficial tissues to the cut surface of the bone. After closure of the wound with sutures a hematoma develops in the empty articular capsule. The blood clot coagulates and later becomes organized by the replacement of the blood by young connective tissue (granulation tissue), made possible by the invasion of the clot by lymph and blood capillaries and veins. The pluripotential cells of the young connective tissue differentiate into macrophages, and fibroblasts which remove and replace the necrotic tissue. The granulation tissue develops into loose connective tissue and the fibroblasts produce numerous collagenous fibers producing a fibrous callus. The fibrous callus is replaced partly by direct bone formation and in the areas under stress by the formation and replacement of cartilagenous tissue by immature coarse-fibrillar bone is then replaced by a mature lamellated bone and followed by reconstruction of the bone to functional stress.

The healing of the resected condyle in the mandible of the monkey shows variations from the healing of fractures. The continued movement of the cut surface of the condylar neck probably separates the blood clot resulting in one on the cut surface and one remaining in the space previously occupied by the condyle. Probably these clots undergo reorganization as in bone fracture and the pluripotential cells in the granulation tissue are probably influenced by the conditions of the immediate environment.

It has been known that under the influence of shearing forces, at a site of fracture the fragments of bone can be covered by a layer of fibrocartilage, thus producing a pseudarthrosis. This functional adaptation can proceed even further, producing a structure very similar to a synovial capsule of a true joint.

The pluripotential cells in the granulation tissue on the cut surface of the condylar neck are possibly stimulated to produce bone by their close proximity to bone at the cut surface. The pluripotential cells in the granulation tissue adjacent to the condyle probably produce fibrous and cartilage tissue which envelops the condyle, under the influence of stresses produced by the functional movement of the mandible, thus producing a fibrocartilage in a manner similar to the formation of a pseudarthrosis.

Since the articular disc was left in place and the fibrous capsule sutured closed after condylectomy and were also present four to eight months after surgery, it is likely that their function is still necessary during the reformation process.

In previous studies on young rhesus monkeys mentioned above, findings in the condylar region after condylectomy for the most part showed a formation of a functional articular process which lacked the morphology of a normal condyle. However, Walker (1960) in a gross study did report a subtotal reformation of the condyle in a unilaterally condylectomized monkey.

The only histologic study of the temporomandibular joint after condylectomy in the monkey was reported by Sarnat in 1957. Thirty months after condylectomy, he observed articulating surfaces on a reformed condyle with no disc interposed. However, there was no evidence of any cartilage being replaced by bone in the condyle-like structure; instead a layer of dense fibrous tissue was attached to the ramus inferiorly and articulated with the temporal bone superiorly.

## Measurements

A true height of the ramus could not be measured in this study since the condyles were removed in all of the animals for histologic study.

The measurements of the heights of the mandibular body and coronoid process, length of the mandibular body, width of the ramus and intermolar distances comparing the operated sides with the unoperated and control sides are unaffected by condylectomy. These findings differ from those of Sarnat and Engel (1951) and Sarnat (1957) which showed significant decreases in the ramus length and mandibular body height, and an increase in ramus width on the operated side after seventeen and thirty-five months, and Walker (1960) who reported decreases in the mandibular body height, coronoid process height, and ramus width on the operated side, and an increase in condylar height on the operated side after eighteen months.

This shows that the mandible continues to grow after condylectomy. Whether the type of growth occuring in the four to eight month period is an adaptive (increase in size only without condylar growth) or developmental (increase in size and attaining a normal shape with condylar growth), it is difficult to determine.

Evidence of cartilage growth in the reformed condyle tends to support the idea of a continued developmental growth. However, evidence of developmental growth cannot be determined until the monkey reaches adulthood.

## Gonial Angle

An increase in acuteness of the gonial angle and antegonial notching in this study is probably due to the alteration in muscular function. The removal of the condyle produces an alteration in the normal masticatory movements as a result of the loss of function of the lateral pterygoid muscle. These alterations in masticatory movements modify normal function of the masseter and medial pterygoid muscles which insert in the area of the gonial angle.

An example of this modification can be described in the opening movement of the mandible. The normal opening movement is caused by a synergistic action of the lateral pterygoids, digastrics, and geniohyoid muscles. The protractive force of the lateral pterygoid muscles act upon the condyles and discs, and simultaneous depression and retracting forces of the geniohyoid and digastric muscles acting on the chin blend to execute the combination of rotatory and translatory movement.

After loss of the lateral pterygoids the opening is done against considerable resistance and the depressors change their direction and power by the fixation of the hyoid bone and contraction of the infrahyoid muscles, thus exerting more force. The resisting force is at the attachments of the masseter and medial pterygoids at the gonial angle.

It is possible that this modified force in the area of the gonial angle causes an increase in bone apposition. An increase in bone at the angle gives the appearance of an increased acuteness of the angle which is formed by the posterior border of the ramus and inferior border of the mandible. An increase in bone at the postero-inferior area of the mandible gives the appearance of an increased antegonial notching.

This finding confirms the increase in acuteness of the gonial angle and antegonial notching on the operated side as reported by Sarnat and Engel (1951), Jarabak and Stuteville (1952), and Sarnat (1957).

Jarabak and Stuteville (1952) stated that the increase in the acuteness of the angle and antegonial notching occurs in response to a change in muscular function. Since the lateral pterygoids are no longer attached to the condylar process, the forward movement of the mandible will depend upon the other muscles. In this case the masseter muscles take over the function of the lateral pterygoids. It is the superficial diagonal fibers which function during the forward movement of the mandible and are attached at the region of the antegonial notch.

Sarnat and Engel (1951) offer an explanation of the deepened antegonial notch as being a result of a lack of downward and forward growth of the mandible coupled with apposition of bone on the posterior border of the ramus.

## Dentition

The open bite in the incisor region of the bilaterally operated animals in this study is probably the result of a rotation of the mandible upward in the posterior region.

The normal closing movement of the jaw is mainly the function of the elevator muscles (masseters, temporalis, and medial pterygoids). The function of the masseter and temporalis muscles is not limited only to the elevation of the mandible. The fibers of the deep portion of the masseter are directed downward and forward if the mandible is in protruded position, thus lending a retracting component which is important during the closing movement of the mandible. The retracting component of the temporalis muscle is in the most posterior oblique fibers, which are directed downward and forward. Therefore the resultant force of these muscles is behind the molars, directed upward and slightly forward coinciding with the long axes of the molar teeth.

When the mandible is closed by the synergistic action of the elevator muscles, the teeth come into contact and the condyles are behind the posterior slope of the articular eminences. A considerable amount of pressure is distributed between the teeth and both temporomandibular joints as a result of this muscular force. Therefore both temporomandibular joints and the occlusal surfaces of the maxillary teeth resist any further upward displacement of the mandible. Choukas (1958, 1960) points out the fact that the insertion of the medial and superior part of the upper head of the lateral pterygoid muscle to the medial anterior corner of the disc acts not only in the forward movement of the disc and condyle, but acts in conjunction with the elevator muscles as a stabilizer of the mandible, disc and eminence during mastication.

If the condyles are removed, the two important resisting points are altered and due to the detachment of the lateral pterygoid muscles an alteration in muscular balance is produced. Thus the stabilization of the normal relation of the mandible, disc, and eminence is lost and the mandible rotates behind the last molar teeth until a new resistant force is met. The new position of the mandible is maintained by the healing of the tissues in this space. As the healing tissues become more organized the new position of the joint becomes stable. When the jaw is closed the last molar teeth will now come into premature contact. This continued force probably causes a depression of the last molars until the contact of the teeth is distributed over a larger number of teeth and eventually reaching a state of equilibrium, thus producing an open bite in the incisor region.

This finding confirms the open bite reported earlier by Sarnat and Engel (1951), Jarabak and Stuteville (1952), Sarnat (1957), and Tomek (1958). Sarnat and Engel believed the open bite to be a result of a rotation and translation of the mandible. The removal of the condyles left a space which filled with fibrous tissue. The masticatory muscles pulled the operated area of the mandible upward and forward in an attempt to close the space resulting in an open bite.

A deviation of the midline of the mandibular incisors toward the operated side observed in one of the unilaterally operated animals can be explained by a disturbance in muscular balance. When the condyle is removed the lateral pterygoid muscle is detached, on the unoperated side the unaffected lateral ptergoid muscle (the principal protractor of the mandible) exerts a pull toward the affected side. This moves the mandible bodily toward the affected side. After a new muscle equilibrium is established bony remodeling occurs, and the deviation is permanent.

It was found, however, that in one of the bilaterally operated animals a deviation of 1 mm occured. In this case the loss of the principal protractor of the mandible is evident on both sides. The remaining group of masticatory muscles function without the aid of the lateral pterygoid muscles. It is probable that the resultant muscle pull was not equal on both sides and a deviation occured to the weaker side. After muscle equilibrium establishes, as described in the unilateral deviation, bony remodeling occurs, and the deviation is permanent.

# CHAPTER VI

## SUMMARY AND CONCLUSIONS

Bilateral and unilateral condylectomies were performed, using a preauricular approach on three groups of young rhesus monkeys. Each group consisted of two monkeys which were sacrificed at intervals of four, six and eight months after surgery. Two monkeys were used as controls which were sacrificed at six and eight months after the start of the experiment.

The findings were observed by the combination of gross post mortem observations, lateral head and antero-posterior roentgenographs, histologic specimens of the temporomandibular joint, impressions of the mandibular dental arch, and measurements of the mandible.

The following results were obtained:

1. All monkeys were able to masticate there normal diet within three days.
2. Open bites of 1 mm were observed in all of the bilaterally operated animals as early as the second postoperative month.
3. Deviations of the mandible were observed in one bilaterally operated animal and one unilaterally operated animal.
4. Within two months after surgery new condyle-like structures were apparent roentgenographically in all of the animals.
5. Measurements of the operated animal mandibles did not differ signifi-

cantly from the control animals.

6. Histologic sections showed a functional temporomandibular joint containing all the structures found in the normal temporomandibular joint of the control animals.

On the basis of the preceding data, the following conclusions were made:

1. A reconstruction and function of the condyle is obtained in young monkeys within four months after condylectomy.
2. No decision could be made as to whether the growth of the mandible, revealed by the measurements of the mandible, was adaptive or developmental because of the limited postoperative period.
3. Bilateral condylectomies in monkeys produce an early open bite which can be attributed to altered mechanics of the temporomandibular joint and muscular function.
4. Sufficient evidence is not available in this study to offer a definitive treatment for condylar injuries in the young child. However, the presence of a reformed functional and growing condyle is encouraging.

## BIBLIOGRAPHY

### References Cited


Avant, F. B., Averill, C. J., and Hahn, W. E. "Changes in the Temporomandibular Joint of Rats Caused by Alterations in the Intermaxillary Relationship of the Teeth," J. D. Res., Aug. 1952, 31:499.

Avis, V. "The Significance of the Angle of the Mandible: an Experimental and Comparative Study," Amer. J. Phys. Anthrop., March 1961, 19:55-61.

Baker, L. W. "Preliminary Study of the Influence of Forces of Occlusion on the Development of the Bones of the Skull," Items Interest, 1911, 33: 110-127.

Baume, L. J., and Becks, H. "The Topogenesis of the Mandibular Permanent Molars: A Roentgenographic and Histologic Study in Rhesus Macaque," Oral Surg., Oral Med., and Oral Path., 1953, 6:850-868.

Baume, L. J., and Hooper, G. W. "The Postnatal Growth of the Mandible in Macaca Mulatta," J. D. Res., Aug. 1951, 30:502.

Belchier, J. "An Account of the Bones of Animals Being Changes to a Red Colour by Aliment Only," Philosoph. Trans., July 1737, 9:1732-1744.

Brash, J. C. "The Growth of the Jaws and Palate," Dental Board of the United Kingdom, (London), 1924.

________. "A Preliminary Note on the Mode of Growth of the Mandible," Brit. Dent. J., 1929, 1:611, 776.

Breitner, C. "Further Investigations of Bone Changes Resulting from Experimental Orthodontic Treatment," Am. J. Orthodont. and Oral Surg., Nov. 1941, 27:605-632.

Brodie, A. G. "The Growth of the Jaws and the Eruption of the Teeth," Oral Surg., Oral Med., and Oral Path., 1948, 1:334.

Charles, S. W. "The Temporomandibular Joint and its Influence on the Growth of the Mandible," Brit. Dent. J., 1925, 46:845-855.

________. "The Development of the Mandible," Transact. Brit. Soc. for Study of Orthodont., 1934.

Choukas, N. C. "The Anatomy of the Temporomandibular Joint in Humans," M. S. Thesis, C. C. D. S., Loyola University Dental School, June 1958.

Choukas, N. C., and Sicher, H. "The Structure of the Temporomandibular Joint," Oral Surg., Oral Med., and Oral Path., 1960, 13:1203-1213.

Cryer, M. H. "Internal Anatomy of the Face," S. S. White Dental Mfg. Co., 1901. Cited from Scott, E. J. "An Experimental Study in Growth of the Mandible," Am. J. Orth. and Oral Surg., 1938, 24:925-934.

Du Hamel. Sur le development et la crue des os des Ahlinaux, Memoires de l'academie royale des sciences de Paris, 1741. Cited from Scott, E. J. "An Experimental Study in Growth of the Mandible," Am. J. Orthod. and Oral Surg., 1938, 24:925-934.

Fawcett, E. "Ossification of the Lower Jaw in Man," J. A. M. A., 1905, XIV, 695.

Harris, J. A. "Growth of the Mandible in the Pig," Nature, 144:522.

Herzberg, F., and Sarnat, B. G. "Radiographic Changes in the Bony Trabecular Pattern in the Mandible of Growing Macaca Rhesus Monkeys Following Condylar Resection," Anat. Rec., Oct. 1962, 144:129-34.

Heurlin, R. J. Jr., Gans, B. J., and Stuteville, O. H. "Skeletal Changes Following Fracture Dislocation of the Mandibular Condyle in the Adult Rhesus Monkey," Oral Surg., Oral Med., and Oral Path., Dec. 61, 14:490-500.

Horowitz, S. L., and Shapiro, H. H. "Modifications of Mandibular Architecture Following Removal of the Temporalis Muscle in the Rat," J. Dent. Res., 31:276-280.

________. "Modification of Skull and Jaw Architecture Following Removal of the Masseter Muscle in the Rat," Am. J. Phys. Anthropol, 1955, 13:301-308.

Humphry, G. M. "On the Growth of the Jaws," Tr. Cambridge Phil. Society, 1864, 11:1.

Hunter, J. Natural History of the Human Teeth. Second edition, London: J. Johnson, 1778.

Jarabak, J. R., and Stuteville, O. H. "Bilateral Mandibular Condylar Resection," J. D. Res., 1952, 31:509.

Jolly, M. "Condylectomy in the Rat. An Investigation of the Ensuing Repair Process in the Region of the Temporomandibular Articulation," Australian D. J., Oct. 1961, 6:243-256.

Kendrick, G. S., and Cameron, J. A. "Observation of the Growth of the Macaca

Rhesus Monkey Skull," J. D. Res., July and Aug. 1959, 38:741-742.

Kolliker, A. A Manual of Human Histology. London: i, 1853. Cited from Rushton, M. "Growth at the Mandibular Condyle in Relation to Some Deformities," Brit. D. J., Feb. 1944, 76:57-68.

Lanfranchi, R. P. "Surgical Reconstruction of the Mandible Following a Condylectomy: In the Rhesus Monkey," M. S. D. Thesis, N. W. D. S., March 1955.

Low, A. "Further Observation on the Ossification of the Human Lower Jaw," J. Anat. Phys., 1909, 44, 83.

Moore, A. W. "Head Growth of the Macaque Monkey as Revealed by Vital Staining," Am. J. Ortho., 1949, 35:654-671.

Pratt, L. W. "Experimental Masseterectomy in Laboratory Rat," J. Mammalogy, 1943, 24:204-212.

Rushton, M. "Growth at the Mandibular Condyle in Relation to Some Deformities," Brit. D. J., Feb. 1944, 76:57-68.

Sarnat, B. G. "Facial and Neurocranial Growth after Removal of the Mandibular Condyle in the Macaca Rhesus Monkeys," Am. J. Surg., 1957, 94:19.

Sarnat, B. G., and Engel, M. B. "A Serial Study of Mandibular Growth after Removal of the Condyle in the Macaca Rhesus Monkey," Plastic and Recons. Surg., 1951, 7:364.

Scott, E. J. "An Experimental Study in Growth of the Mandible," Am. J. Ortho. and Oral Surg., 1938, 24:925-934.

Sicher, H. "The Growth of the Mandible," Journ. of Periodontology, 1945, 16: 87-93.

________. "The Growth of the Mandible," Am. J. Orthodont. and Oral Surg., 1947, 33:30.

________. Oral Anatomy. 2nd ed. St. Louis: The C. V. Mosby Co., 1952.

Stuteville, O. H., and Lanfranchi, R. P. "Surgical Reconstruction of the Temporomandibular Joint," Am. J. Surg., Dec. 1955, 90:940-950.

Symons, N. B. B. "Studies in the Growth and Form of the Mandible," Dent. Rec., 1951, 71:41-53.

Tomek, S. "Postoperative Growth of the Lower Jaw after Surgical Removal of the Condyles in Macaca Rhesus Monkeys," Dent. Abst., 1959, 4:32.

Tomes, J. A System of Dental Surgery. London: John Churchill, 1859.

Walker, R. V. "Traumatic Mandibular Condylar Fractures Dislocation: Effect on Growth in the Macaca Rhesus Monkey," Amer. J. Surg., Dec. 1960, 100: 850-863.

Washburn, S. L. "The Effects of Facial Paralysis on the Growth of the Skull of Rat and Rabbit," Anat. Rec., Feb. 1946, 94:163-168.

Watt, D. G., and Williams, C. H. M. "The Effect of the Physical Consistency of Food on the Growth of the Mandible and Maxilla of the Rat," Amer, J. Orthodont., 1951, 37:895-928.

Weinmann, J. P., and Sicher, H. Bone and Bones, Fundamentals of Bone Biology. 2nd ed. St. Louis: The C. V. Mosby Co., 1955.

## Secondary References

Barber, C. G., Green, and Cox, G. J. "Effects of the Physical Consistency of Diet on the Condylar Growth of the Rat Mandible," J. Dent. Res., May and June 1963, 42:848-51.

Berry, D. C. "The Relationship Between Some Anatomical Feature of the Human Mandibular Condyle and Its Appearance on Radiographs," Arch. Oral Biol. Aug. 60, 2:203-8.

Bhashue, S. N., Weinmann, J. P., and Shour, I. "Role of Meckel's Cartilage in the Rat Mandible," J. D. Res., 1952, 31:500.

Bjork, A. "Variations in the Growth Pattern of the Human Mandible: Longest Radiographic Study by the Implant Method," J. Dent. Res., Jan. and Feb. 1963, 2:400-11.

Blevins, C., and Gores, R. T. "Fractures of the Mandibular Condyloid Process: Results of Conservative Treatment in 140 Patients," J. Oral Surg., Sept. 61, 19:392-407.

Calhoun, N. R., et al. "Effects of Plaster of Paris Implants on Osteogenesis in the Mandible of Dogs," J. Dent. Res., Sept.-Oct. 63, 42:1244.

Chapman, H. "Growth of the Jaws with Special Reference to the Milk Dentition," Dental Rec., 1936, 56:369.

Engel, M. B., and Brodie, A. G. "Condylar Growth and Mandibular Deformities," Oral Surg., Oral Med. & Oral Path., 1948, 1:790.

Jarabak, J. R. "Regeneration of the Mandibular Condyle in the Rat," Abstract J. D. Res., Oct. 1950, 29:5, 692-693.

________. "Subcondylar Fractures of the Mandible: Research and Treatment," Am. J. Ortho., 1954, 40:729-55.

Jarabak, J. R., and Kamins, M. "Masseter Muscle in Condylar Regeneration of the Rat," J. D. Res., Aug. 1952, 31:509.

Keith, A., and Campion, G. "A Contribution to the Mechanism of Growth of the Human Face," Dent. Rec., 1922, 42:61-88.

Kock, J. C. "The Laws of Bone Architecture," Am. J. Anat., 1917, 21:177-298.

Manson, J. D., and Lucas, R. B. "A Microradiographic Study of Age Changes in the Human Mandible," Arch. Oral. Biol., Nov.-Dec. 62, 7:761-9.

Robinson, I. B., and Sarnat, B. G. "Growth Pattern of the Pig Mandible: A Serial Roentgenographic Study Using Metallic Implants," Am. J. Anat., 1955, 96:37-64.

Rushton, M. A. "Some Aspects of Antero Posterior Growth of the Mandible," D. Rec., 1948, 68:80.

Sarnat, B. G. (ed.) The Temporomandibular Joint. Springfield, Ill.: Charles C. Thomas, 1951.

Scott, J. H. "The Comparative Anatomy of Jaw Growth and Tooth Eruption," Dent. Rec., 1951, 71:149-167.

Sicher, H. "Functional Anatomy of the Temporomandibular Joint," Reprint from The Temporomandibular Joint. Sarnat, B. G. ed. 2nd ed. Springfield, Ill.: Charles C. Thomas, 1964.

Thoma, K. "Principal Factors Controlling Development of Mandible and Maxilla," Am. J. Orthod. and Oral Surg., 1938, 24:171-179.

Thompson, J. R. "Asymmetry of the Face," J. A. D. A., Dec. 1943, 30:1859-1871.

Townsley, W. "The Influence of Mechanical Factors on the Development and Structure of Bone," Am. J. Phys. Anthrop., 1948, 6:25-45.

# APPENDIX A

FIGURE 43

Photograph of anesthetized monkey.

FIGURE 44

Photograph of surgical area shaved.

FIGURE 45

Photograph of animal draped and ready for surgery.

FIGURE 46

Photograph of incision of skin.



PLATE XVIII

Figure 43

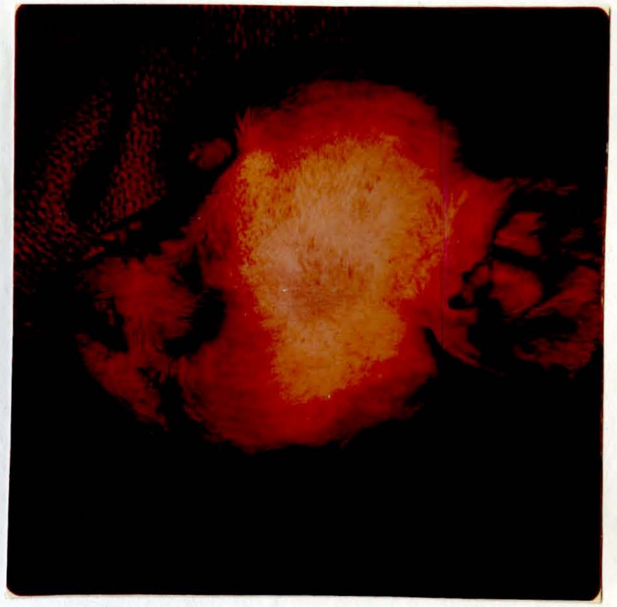

Figure 44

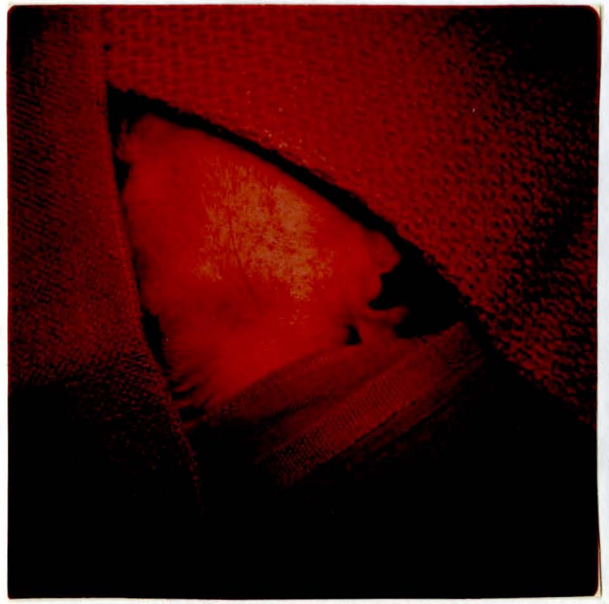

Figure 45

Figure 46

FIGURE 47

Photograph of skin reflected.

FIGURE 48

Photograph of superficial tissues reflected.

FIGURE 49

Photograph of deep blunt dissection being made.

FIGURE 50

Photograph of condylar neck exposed.



PLATE XIX

Figure 47

Figure 48

Figure 49

Figure 50

FIGURE 51

Photograph of sectioned condylar neck.

FIGURE 52

Photograph of condyle removed and empty condyle space.

FIGURE 53

Photograph of deep tissues being sutured.

FIGURE 54

Photograph of deep tissue sutured in place.



PLATE XX

Figure 51

Figure 52

Figure 53

Figure 54

FIGURE 55

Photograph of skin closed with interrupted sutures.

FIGURE 56

Photograph of plastic bandage being applied.

FIGURE 57

Photograph of condyle.



PLATE XXI

Figure 55

Figure 56

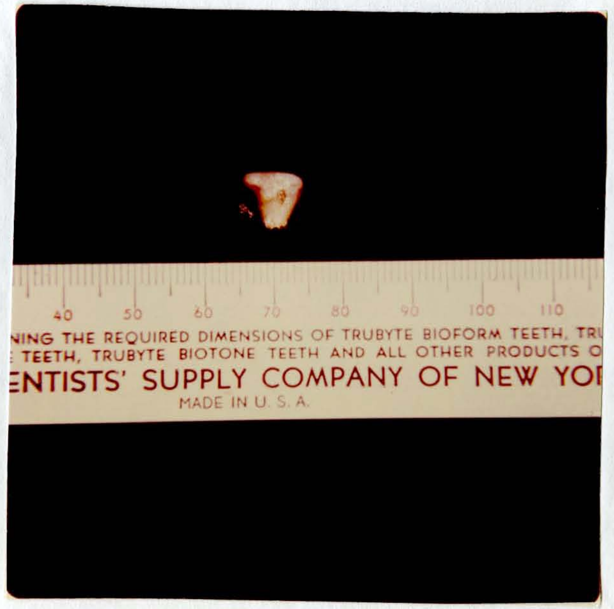


Figure 57

APPENDIX B

TABLE 3

POSTOPERATIVE FINDINGS IN MONKEY NUMBER 1,
LEFT UNILATERAL CONDYLECTOMY

| Period Observed | Weight (lbs) | Dentition | Length of Hand (mm) | Midline | Open Bite | Intermolar Distance, 2nd Decid. (mm) | Intermolar Distance, 1st Perm. (mm) |
|---|---|---|---|---|---|---|---|
| At Surgery | 5.5 | All Deciduous | 65.0 | Normal | None | 16.2 | - |
| 2 Months | 5.0 | Deciduous and 6's | 72.0 | Normal | None | 16.3 | 17.5 |
| 4 Months | 6.2 | Same | 80.0 | Normal | None | 16.2 | 17.5 |
| 6 Months | 6.5 | Same | 86.0 | Normal | None | 16.2 | 17.6 |
| 8 Months | 6.8 | Erupting<br>7 7 | 88.0 | Normal | None | 16.2 | 17.6 |

TABLE 4

POSTOPERATIVE FINDINGS IN MONKEY NUMBER 2,
BILATERAL CONDYLECTOMY

| Period Observed | Weight (lbs) | Dentition | Length of Band (mm) | Midline | Open Bite | Intermolar Distance, 2nd Decid. (mm) | Intermolar Distance, 1st Perm. (mm) |
|---|---|---|---|---|---|---|---|
| At Surgery | 5.0 | All Deciduous | 70.0 | Normal | None | 15.8 | - |
| 2 Months | 5.5 | Deciduous and 6's | 78.0 | Normal | 0.5 mm | 15.8 | 16.2 |
| 4 Months | 6.2 | Same | 82.0 | Normal | 1.0 mm | 15.8 | 16.2 |
| 6 Months | 6.5 | Deciduous $\frac{6\ 2\ 1\quad 1\ 2\ 6}{6\quad 1\quad 1\quad 6}$ | 87.0 | Deviation Left 1.0 mm | 1.0 mm | 15.8 | 16.2 |
| 8 Months | 7.0 | Same | 88.0 | Same | 1.0 mm | 15.8 | 16.2 |

TABLE 5

POSTOPERATIVE FINDINGS IN MONKEY NUMBER 3,
LEFT UNILATERAL CONDYLECTOMY

| Period Observed | Weight (lbs) | Dentition | Length of Hand (mm) | Midline | Open Bite | Intermolar Distance, 2nd Decid. (mm) | Intermolar Distance, 1st Perm. (mm) |
|---|---|---|---|---|---|---|---|
| At Surgery | 5.0 | All Deciduous | 70.0 | Normal | None | 16.9 | - |
| 2 Months | 5.0 | Deciduous and 6's | 73.0 | Normal | None | 16.9 | 17.7 |
| 4 Months | 6.0 | Same | 74.0 | Deviation Left 1.0 mm | None | 16.9 | 17.7 |
| 6 Months | 6.3 | Same | 76.0 | Same | None | 16.9 | 17.9 |

TABLE 6

POSTOPERATIVE FINDINGS IN MONKEY NUMBER 4, BILATERAL CONDYLECTOMY

| Period Observed | Weight (lbs) | Dentition | Length of Hand (mm) | Midline | Open Bite | Intermolar Distance, 2nd Decid. (mm) | Intermolar Distance, 1st Perm. (mm) |
|---|---|---|---|---|---|---|---|
| At Surgery | 5.0 | All Deciduous | 70.0 | Normal | None | 16.2 | - |
| 2 Months | 5.0 | Deciduous and 6's | 75.0 | Normal | 1.0 mm | 16.0 | 16.3 |
| 4 Months | 6.4 | Same | 78.0 | Normal | 1.0 mm | 16.1 | 16.2 |
| 6 Months | 7.5 | Same | 80.0 | Normal | 1.0 mm | 16.1 | 16.3 |

TABLE 7

POSTOPERATIVE FINDINGS IN MONKEY NUMBER 5, LEFT UNILATERAL CONDYLECTOMY

| Period Observed | Weight (lbs) | Dentition | Length of Hand (mm) | Midline | Open Bite | Intermolar Distance, 2nd Decid. (mm) | Intermolar Distance, 1st Perm. (mm) |
|---|---|---|---|---|---|---|---|
| At Surgery | 3.5 | All Deciduous | 65.0 | Normal | None | 14.0 | - |
| 2 Months | 3.5 | Deciduous Erupting 6's | 68.0 | Normal | None | 14.1 | 15.3 |
| 4 Months | 4.5 | Deciduous and 6's | 70.0 | Normal | None | 14.1 | 15.4 |

TABLE 8

POSTOPERATIVE FINDINGS IN MONKEY NUMBER 6,
BILATERAL CONDYLECTOMY

| Period Observed | Weight (lbs) | Dentition | Length of Hand (mm) | Midline | Open Bite | Intermolar Distance, 2nd Decid. (mm) | Intermolar Distance, 1st Perm. (mm) |
|---|---|---|---|---|---|---|---|
| At Surgery | 3.0 | All Deciduous | 65.0 | Normal | None | 15.4 | - |
| 2 Months | 3.0 | Deciduous Erupting 6's | 66.0 | Normal | 1.0 mm | 15.4 | 16.9 |
| 4 Months | 4.3 | Deciduous and 6's | 70.0 | Normal | 1.0 mm | 15.4 | 16.9 |

TABLE 9

POSTOPERATIVE FINDINGS IN MONKEY NUMBER 7, CONTROL

| Period Observed | Weight (lbs) | Dentition | Length of Hand (mm) | Midline | Open Bite | Intermolar Distance, 2nd Decid. (mm) | Intermolar Distance, 1st Perm. (mm) |
|---|---|---|---|---|---|---|---|
| Beginning | 3.5 | All Deciduous | 65.0 | Normal | None | 17.1 | - |
| 2 Months | 4.0 | Deciduous and 6's | 68.0 | Normal | None | (Records Lost) | (Records Lost) |
| 4 Months | 4.5 | Same | 73.0 | Normal | None | 17.1 | 18.9 |
| 6 Months | 5.0 | Same | 78.0 | Normal | None | 17.1 | 18.9 |
| 8 Months | 6.8 | Same | 80.0 | Normal | None | 17.1 | 18.9 |

TABLE 10

POSTOPERATIVE FINDINGS IN MONKEY NUMBER 8, CONTROL

| Period Observed | Weight (lbs) | Dentition | Length of Hand (mm) | Midline | Open Bite | Intermolar Distance, 2nd Decid. (mm) | Intermolar Distance, 1st Perm. (mm) |
|---|---|---|---|---|---|---|---|
| Beginning | 4.5 | All Deciduous | 70.0 | Normal | None | 14.9 | - |
| 2 Months | 5.0 | Same | 74.0 | Normal | None | 14.9 | - |
| 4 Months | 5.5 | Deciduous and 6's | 78.0 | Normal | None | 14.9 | 15.8 |
| 6 Months | 6.0 | Same | 80.0 | Normal | None | 14.9 | 15.8 |

APPROVAL SHEET

The thesis submitted by Dr. Julius M. Guccione has been read and approved by three members of the faculty of the Graduate School.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

5/17/65
Date

Nicholas C. Chenkos, Ph.D., M.S.
Signature of Adviser